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**Federal Highway
Administration**

Safety Restoration During Snow Removal—Guidelines

Synthesis Report

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February 1991

Office of Implementation
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

Implementation
advancing highway technology

FOREWORD

This report addresses findings from a study on the safety aspects of nonfunctioning highway safety features which can occur with maintenance snow removal activities during emergency and post-snowstorm cleanup operations. Remedies to the resulting hazards are also identified.

During the study, maintenance engineers in seven State highway agencies and one Turnpike authority were interviewed by letter. On site visits were made to five States where identified safety hazards and their remedies were analyzed. The special hazard of snow and ice on truck escape ramps was also identified and analyzed.

The winter safety hazards identified were ranked according to their risk, severity, correctability, and exposure. The remedies identified were rated according to their difficulty. In many cases, the cleanup remedies can be accomplished with little or no additional cost.

The report should be of interest to State and local maintenance Engineers concerned with proper and safe winter snow and ice control activities.

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Director, Office of Implementation

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16. Abstract

Significant manpower and financial resources are expended annually by State, county, and municipal governments on snow and ice control programs. This research addressed the hazards associated with nonfunctioning highway safety features that occur with snow removal operations during both emergency and post-snowstorm cleanup, and how these hazards can be remedied.

A review of available literature and a limited analysis of winter accident data revealed 17 snow-related safety hazards. These were given a priority ranking and grouped into four categories: most serious, serious, important, and special. Most serious hazards include superelevated and sharp curves; bridge parapets, rails and curbed areas; plows and other snow removal equipment, and intersections and interchanges. Hazards ranked serious are addressed after most serious hazards. Serious hazards include guardrails; snow plow equipment; stalled and abandoned vehicles; narrow medians, shoulders, and gore areas; and safety-shaped barriers. Important hazards receive attention during post-snowstorm cleanup operations, but not immediate attention except where an obvious problem exists. Important hazards include drains, culverts, and channels; snow or ice windrows; shallow cut areas; at-grade railroad crossings; pavement obstructions; obscured highway signs; and impact attenuators. Truck escape ramps are a special hazard in mountainous areas.

Remedies to the hazards presented were confined to practices, procedures, equipment, and manpower resources available to State highway agencies. The most important recommendation from the study is that the order of cleanup during emergency snow removal operations and post-snowstorm removal operations should follow a priority ranking based on the hazards that exist.

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SI* (MODERN METRIC) CONVERSION FACTORS

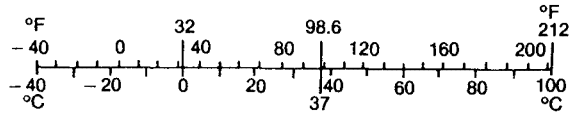
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

NOTE: Volumes greater than 1000 L shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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Executive Summary

Snow and ice storms have long been a concern to the traveling public. The advent of the motor vehicle, and eventually of all-weather roads, resulted in the development of snow and ice removal techniques.

Significant manpower and financial resources are expended annually by State, county, and municipal governments on snow and ice control programs. In 1984 these governments spent over $1 billion annually on snow and ice control on the nation's highways.

Accidents happen when the safety functions of appurtenances such as bridge rails, safety-shaped barriers, guardrails, and crash cushions are degraded by heavy accumulations of snow and ice. Accidents are also generated when snow accumulations reduce sight distance or visibility at intersections, curves, and ramps.

Once a roadway network is reopened to traffic after a storm, maintenance crews perform post-snowstorm cleanup work. This research addressed the safety associated with nonfunctioning highway features that occur with snow removal operations during both emergency and post-snowstorm cleanup, and how these hazards can be remedied.

Maintenance engineers in seven State highway or Turnpike agencies were interviewed. Visits were made to five States to identify hazards and their remedies. Remedies were confined to those practices, procedures, equipment, and manpower resources that are available to State highway agencies. Available literature also was reviewed and some winter accident data were analyzed.

Winter hazards that were identified nationwide are presented in table 1 in priority order. The identified hazards were ranked according to their judged risk, severity, correctability, and exposure. The special hazard of snow and ice on truck escape ramps was also identified.

Remedies identified for the hazards listed are shown in table 2. The remedies fall into two groups: those associated with emergency snow removal and those associated with post-snowstorm cleanup operations. Emergency snow removal should be accomplished in a manner that will minimize the number of hazards created.

The remedies to be accomplished during cleanup were rated according to their difficulty. In many cases, cleanup remedies can be done with little additional cost; however, hazards left uncorrected can become very difficult and costly to remedy.

A major recommendation from the study was that there should be a priority in cleanup activities so that the most serious hazards are remedied first. A four-step procedure was developed that can be used by maintenance engineers to prepare a prioritized list of cleanup activities specific to their maintenance area. These steps are to (1) obtain an inventory of existing features, (2) consider the hazards, (3) determine remedies, and (4) develop local cleanup priorities.

An application of the prioritization procedure was developed, as were three scenarios of typical maintenance units in different areas of the United States to show its application.

INTRODUCTION

1. History of the Problem

Snow and ice storms have long been a concern to the traveling public. Prior to the development of the automobile, travel during winter was limited. The advent of motor vehicles, and eventually of all-weather roads, resulted in the development of improved snow and ice removal techniques.

Significant manpower and financial resources are expended annually by State, county, and municipal governments on snow and ice control programs. In 1984 these governments spent over $1 billion on snow and ice control on the nation's highways.(2) Although such expenditures have been in the interest of public safety and of maintaining a free-flowing transportation network, there is a limit to the amount of expenditures that can be justified. Thus, highway administrators and maintenance engineers are faced with a need to take an economic approach to snow and ice control. They must draw upon materials, equipment, and techniques that lead to quick and relatively inexpensive solutions to winter maintenance problems. They must also allocate wisely their limited resources throughout the statewide highway network, while providing uniformity in snow and ice control for the motoring public.

Once a roadway network is reopened to traffic after a storm, maintenance crews perform post-snowstorm cleanup work. Cleanup includes removing accumulated snow adjacent to the shoulder; removing snow to provide adequate sight distance in curves and intersections; clearing snow from drainage structures; loading and hauling snow from bridges, cuts, gore areas, narrow medians, and other areas where storage is not possible; and clearing snow from guardrail, longitudinal barriers, and impact attenuators. Maintenance personnel are also alert to snow-melt conditions in which snow-melt refreezes at night.

Accidents happen when the safety functions of appurtenances such as bridge rails, safety-shaped barriers, guardrail, and crash cushions are degraded by heavy accumulations of snow and ice. Accidents are also generated when snow accumulation reduces sight distance or visibility at intersections, curves, and on-ramps.

Restoring these highway safety features to full operational effectiveness as soon as possible after emergency snow removal activities is the goal of State highway agencies and the Federal Highway Administration (FHWA). The snow and ice control policy of several highway agencies addresses in a general manner some but not all of the above safety hazards. Maintenance engineers, supervisors, and foremen exercise judgment to cover critical safety-related situations not dictated by their standard snow and ice control policy.

2. Scope and Objectives of the Research

This research addressed the hazards associated with nonfunctioning highway safety features that occur with snow removal operations during both emergency and post-snowstorm cleanup, and how these hazards can be remedied. Recommendations are confined to practices, procedures, equipment, and manpower resources that are available to State highway agencies.

The objectives of this research were to:

- Determine the nature and extent of the highway safety problems of nonfunctioning highway features that are the result of emergency snow removal practices.
- Identify locations, such as snow buildup at intersections and curves, snow-melt freezing at night on the pavement, and snow buildup around bridge rails, impact attenuators, guardrail, etc., where emergency snow removal practices or inattention during post-snowstorm cleanup operations may cause a safety hazard.
- As appropriate, determine how best to reduce or eliminate the hazard through better use of the State highway department's existing manpower and equipment.
- Develop recommendations which will enable State Maintenance Engineers or State District Maintenance Engineers to prioritize their post-snowstorm cleanup operations so to minimize the hazards to the traveling public.
- Prepare slides and a script that will enable the FHWA to produce a 20-minute slide-tape show identifying potential hazards and demonstrating techniques to best eliminate the hazard.

Visits were made to five States to discuss, observe, and photograph post-snowstorm cleanup activities. Cleanup operations at truck escape ramps, identified as a special hazard, were also investigated. A slide-script package for highway agency maintenance engineers presenting guidelines for post-snowstorm cleanup operations was developed.

After this introductory chapter, the report continues with a description of the study's methodology and follows with a discussion of the hazards motorists face during and following snow and ice storms, and the remedies for such conditions. A procedure for developing priorities in snow removal operations is presented next, along with some scenarios typical maintenance units use to illustrate the procedure. Finally, study conclusions and recommendations are presented.

METHODOLOGY

This chapter describes the methodology used in conducting the study, including the literature review, telephone interviews, accident data collection and analysis, hazard definitions, hazard priority ranking, and State visits.

1. Literature Review

The literature was searched for information on safety problems, snow removal, ice control, and cleanup operations. A computerized literature search of Transportation Research Information Service (TRIS) and National Technical Information Service (NTIS) abstracts produced 126 TRIS and 36 NTIS reference abstracts. Each abstract was reviewed for its value to this study and was rated as being of potential, secondary, or negligible value. Most of the relevant references dealt with winter maintenance activities. Few dealt with traffic accidents except for studies of safety in relation to studded tires or the effects of salt. Little in the literature dealt with winter safety relating to highway appurtenances or features.

References identified through the computerized literature search, the Midwest Research Institute (MRI) library, and the Linda Hall Library of Science and Technology were obtained and reviewed. References unknown to the project team were also provided by the Contracting Officer's Technical Representative (COTR). Information pertaining to winter safety problems in relation to emergency snow removal, ice control, and post-snowstorm cleanup operations was extracted. The literature review is presented as appendix A.

2. Telephone Interviews

Letters requesting information about snow removal policies and on winter accident statistics were mailed to 193 persons in 44 State highway agencies, 2 cities, 14 toll road agencies, and 6 Canadian highway agencies for a total of 66 agencies. Responses were received from 64 percent of the agencies (34 State highway, 1 city public works, 6 Canadian highway, and one toll road agencies).

Policies were grouped by region of the country and then evaluated to determine agencies that addressed cleanup operations and safety-related problems resulting from winter conditions. The State highway agencies of Colorado, Minnesota, Nebraska, New York, Ohio, West Virginia, and the New York Thruway Authority were selected to be interviewed.

Telephone interviews were conducted with personnel in seven State highway agencies to determine how potentially hazardous highway features are identified and how priorities for correction are established and assigned. The interviews sought to identify hazards to the traveling public when these features are not functioning because of snow and ice buildups, or drifting. Maintenance engineers and supervisors in headquarters and district offices were asked to comment on problem areas

related to snow removal, ice control, and cleanup operations. The results of the survey were summarized into two categories: hazards associated with particular highway features and hazards associated with specific conditions. Survey results were used in the priority ranking procedure to produce a ranked list of potential hazards associated with winter road conditions. An Interim Report of this research project presented the Phase I research results.

3. Accident Data Collection and Analysis

The goals of the accident data collection and analysis were to obtain winter accident information that would aid in the selection of agencies to be interviewed and to obtain information that would aid in the prioritizing of highway features made more hazardous by winter road conditions. The project team was aware early in the project that a rigorous analysis of accident data would not yield a great deal of information relating to snow removal or cleanup operations. The analysis was more useful in determining the general magnitude of winter traffic accidents by describing the frequency, severity, and type of highway accidents that occur during winter conditions.

4. Hazard Definitions

In developing hazard definitions, an initial list of hazardous areas was prepared from literature sources and the personal experience of the project staff. A definition of each potential hazard was developed which included the source of problem, winter maintenance operation involved, highway feature affected, unsafe condition created, references, number of agencies providing information, possible solutions and ease of implementation, priority ranking, and discussion of the ranking. As information was learned from the literature review, interviews, and priority ranking, it was added to the definition.

5. Hazard Priority Ranking

Priority ranking of potential winter hazards became the basis of a prioritized list of hazards for use by highway agencies. The three principal engineers on the project developed a list of hazardous features and conditions that State highway agencies might face in performing emergency snow removal and cleanup operations. To determine the rankings, the staff utilized the problem definitions, literature review, accident statistics, and the results of telephone interviews. The prioritized list of hazards included an overall combined ranking and rankings by highway class (urban freeway, rural freeway, urban nonfreeway and rural nonfreeway). The prioritized list of hazards in table 1 is the result of the combined ranking. The hazard priority ranking methodology is described in appendix B.

Table 1. Winter safety hazards.

Most Serious

- Superelevated and sharp curves
- Bridge parapets, rails, and curbed areas
- Plows and other snow removal equipment
- Intersections and interchanges

Serious

- Guardrail
- Snow plow alignment
- Stalled or abandoned vehicles
- Narrow medians, shoulders, and gore areas
- Safety-shaped barriers

Important

- Drains, culverts, and channels
- Snow or ice windrows
- Shallow cut areas
- At-grade railroad crossings
- Pavement obstructions
- Obscured highway signs
- Impact attenuators

Special

- Truck escape ramps

6. State Visits

Visits were made to Colorado, Montana, New York, Ohio, and Wisconsin in the winters of 1985-86 and 1986-87 to learn about post-snowstorm cleanup activities. These visits were coordinated through headquarters and district offices.

The visits were to be scheduled shortly after a snowstorm so that cleanup could be observed. The ten States that agreed to let researchers discuss and observe cleanup operations were placed on "ready-to-go" status. When a storm requiring cleanup occurred, the State contact person telephoned the Principal Investigator, described weather conditions, and set appointments. Fickle winter weather made it difficult sometimes to observe cleanup operations under "ideal" conditions.

State visits consisted of discussions with headquarters or district maintenance engineers and field observation of winter road conditions, which included cleanup activities. Discussions with maintenance engineers focused on how hazardous conditions were identified and remedied. Procedures, equipment, manpower, problems, and weather conditions also were discussed.

During field visits, cleanup activities were observed and photographed. Discussions also were held with equipment operators to learn how and why cleanup procedures were done and about cleanup and safety problems encountered. It was learned from discussions with maintenance engineers, for example, that driving a snow plow is much more dangerous than originally perceived. Slow-moving plows are subject to many "close-call" accident situations daily. Motorists and plow operators cannot see each other because of blowing snow. Riding in a plow, researchers discovered that visibility is restricted and operating a snow plow requires utmost concentration.

Researchers also drove urban and rural State highways photographing winter conditions that presented hazards to motorists. Photographic slides were taken using a 35-mm camera with 50-mm and 70-210-mm telephoto lenses. Slides also were obtained from State highway agencies. These were mostly of emergency snow removal activities and equipment. Few slides of post-snowstorm cleanup operations were obtained from the States.

HAZARDS AND REMEDIES

This chapter discusses the hazards that motorists face as a result of snow and ice buildup at highway features and the remedies to these hazards that are applied by highway agency maintenance departments. Hazards are best prevented during emergency snow removal operations or remedied during post-snowstorm cleanup operations.

Hazards and remedies are presented in three groups and according to their order of importance: most serious, serious, and important. Table 2, placed at the end of this chapter, lists the hazards and remedies discussed in this chapter.

1. Most Serious Hazards

The four hazards ranked most serious are considered quite serious and should therefore receive priority treatment in emergency snow removal and post-snowstorm cleanup operations. The four hazards ranked as most serious and in descending order are superelevated and sharp curves; bridge parapets, rails, and curbed areas; plows and other snow removal equipment; and intersections and interchanges.

a. Superelevated and Sharp Curves

Snow or ice accumulation on the highside shoulder of superelevated ramps and superelevated curves, especially those without reverse shoulder slopes, received the highest ranking of 1 of 17 overall. (See appendix B for composite scores and ranks by highway class.) Snow piled in the middle of sharp curves reducing sight distance (visibility) of approaching vehicles is a related hazard. Snow stored on the high side of curves is subject to melting and refreezing, creating sheets or patches of ice on the once-cleared road surface. "Freezeback" usually occurs when afternoon sun melts piled snow, allowing moisture to run back across the previously cleared driving surface and to freeze in the cold of early evening. The condition is especially hazardous because it is unexpected and unseen by motorists. Chemicals used to melt snow and ice which become diluted in the resulting water aggravate the situation. Superelevated curves, ramps, and bridge decks that have a straight cross section from curb to curb are especially affected by refrozen snow-melt.

High-volume traffic routes are affected most because more vehicles confront the refrozen snow-melt. Refrozen snow-melt can remain for a long period of time if not treated.

To prevent melted snow from refreezing on superelevated ramps or curves, snow should be plowed to the low side of the roadway during emergency snow removal unless it is possible to push or wing snow over the highside edge of the shoulder line or ditch. At the inside of curves, snow should not be stored snow where it will reduce visibility of approaching vehicles. Where snow has been stored on the high side of curves, it should be removed and sand applied to wet spots to increase friction between tires and the road surface. Packed snow may have to be removed with a grader or front-end loader.

Figure 1 shows a superelevated ramp and curve (figure 1a), with snow on the high side of the ramp in figure 1b and the curve in figure 1c that can melt and run across the pavement during thawing. This hazard can be remedied during emergency snow removal operations by pushing snow to the low side of the curve, as shown in figure 1d.

b. Bridge Parapets, Rails, and Curb Areas

Snow or ice accumulation at bridge parapets, rails, and curbed areas is a most serious hazard, as indicated by its overall rank of 2.5 (tied for second place). An associated but less serious hazard is snow plows casting snow from overhead bridges onto adjacent roadway, railroad tracks, or properties below.

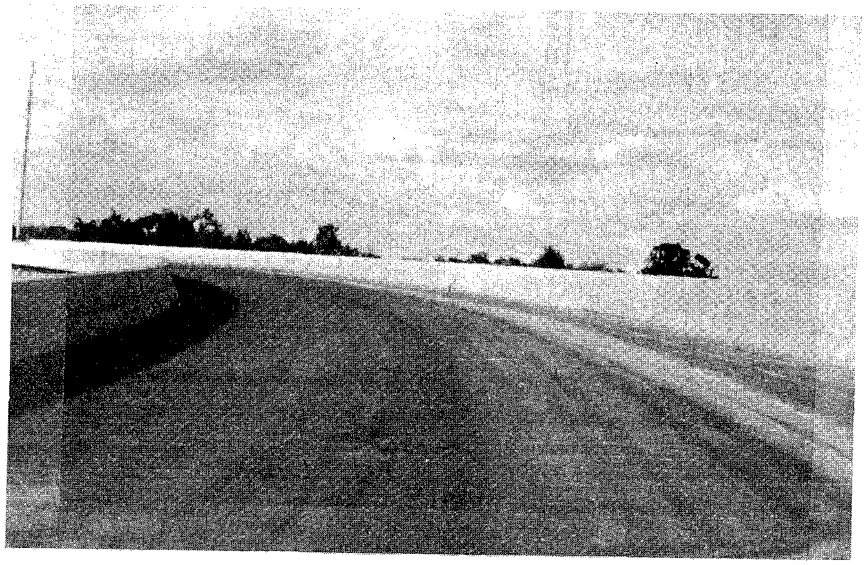
During emergency snow removal on bridges, snow often gets plowed against parapets and rails. Hard-packed snow piled at two-thirds the height of the bridge parapet or rail changes its shape and creates the potential for vehicle ramping. The most critical areas on a bridge are the parapet, rail, or curb along the north side of an east-west-oriented bridge. Because that side is always shaded, melting is inhibited. Safety-shaped bridge parapets, regular bridge parapets, and open-pipe bridge rails are subject to vehicle ramping which can result in fatal injuries.

Light snow can be pushed off short bridge decks with a plow. Plow speed must be reduced while snow removal vehicles are working on overpasses so as to prevent throwing snow over parapets or through railings onto the roadway, railroad tracks, or buildings below. A snow fence mounted against a bridge rail will lessen the amount of snow cast through railings.

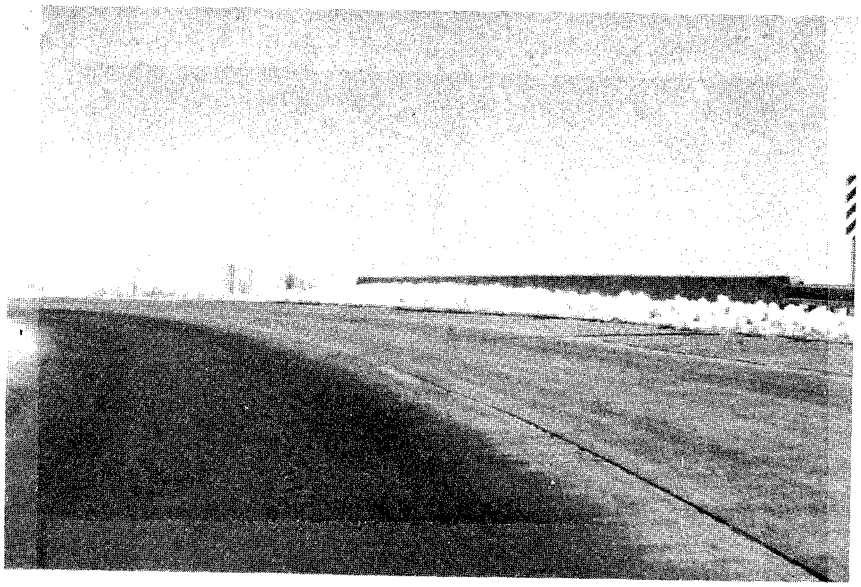
Plowing in tandem can be used to clear an entire bridge deck, including railings. Plowing in tandem is most safely accomplished under well-lit conditions and when traffic is light. A moving barrier such as a police vehicle can be used to prevent motorists from passing the convoy of plows.

Snow and ice on a bridge parapet, rail, or curb should be removed completely. Otherwise, when the temperature rises and melting occurs, moisture from the remaining snow may run back across the pavement and create "freeze-back" conditions. An extreme temperature increase can even cause unsupported snow accumulation to collapse and spill onto the travel surface.

Snow accumulation should be removed entirely by either pushing the snow to the end of the bridge and over the fill area, blowing, or loading and hauling away. Before it is blown into dump trucks, snow pulled from the parapet with a plow blade should be checked for objects which could damage equipment. The clearing of snow and ice from bridges should include removing snow and ice from drop inlets, scuppers, and downspouts to prevent clogging. A flashing arrow panel, an excellent alerting device, should be considered for traffic control.



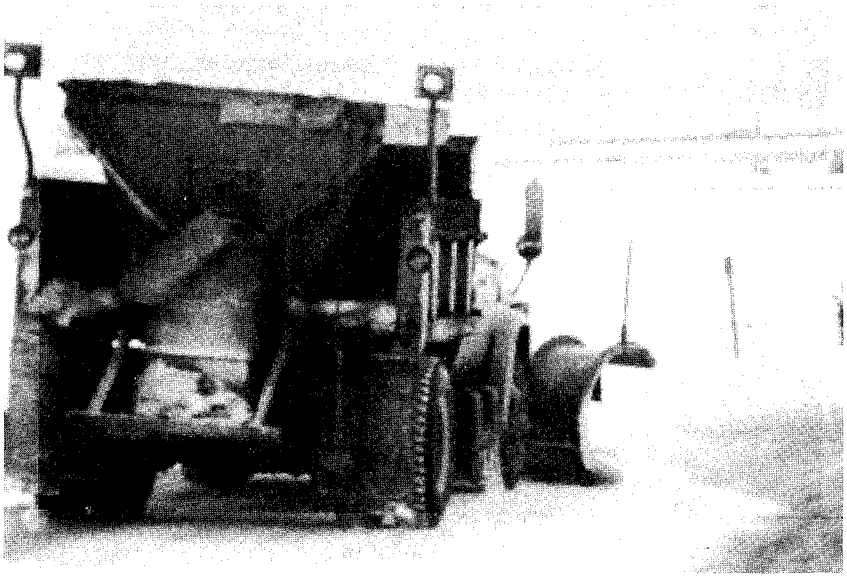
(a)



(b)

Figure 1. Snow on the highside of superelevated ramps and curves.

(c)



(d)

Figure 1. Snow on the highside of superelevated ramps and curves (concluded).

Figure 2 shows snow ramps around a bridge parapet. Figures 2 a and b show how snow tends to form a solid ramp especially in a shaded area on the north side of an east-west parapet. Remedies for this hazard are shown in figure 2 c and d. Where bridges are not over roadways, railroad tracks, or buildings, snow can be pushed over the parapet. Otherwise, it is pushed to the end of the bridge.

c. Plows and Other Snow Removal Equipment

Vehicles colliding with snow plows and other snow removal equipment is a most serious hazard, as indicated by its overall rank of 2.5. The difference in operating speed between snow removal vehicles and traffic vehicles and the poor visibility created by blowing snow create the potential for serious collisions. Collisions usually involve vehicles running into the rear of snow plows or vehicles striking the plow when passing. Faster moving, impatient, or indifferent motorists often tailgate or try to pass plows. Sometimes while completing their passing maneuver, they misjudge the snow plow's speed and hook their rear bumper onto the plow blade. Head-on accidents have also occurred when snow plows are near the centerline facing oncoming traffic.

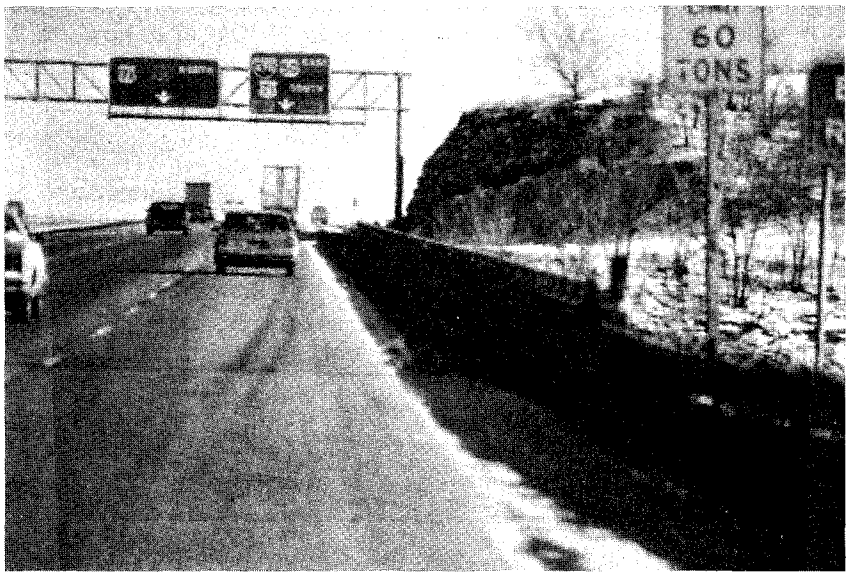
Snow plow operators complain about motorist driving habits during snow removal operations. Because motorists generally do not understand snow plowing operations, they frequently misjudge the width, length, and speed of the snow plowing vehicle. Once the roadway is open to traffic during snow plowing, travel speeds will increase to their normal level thereby increasing the severity of a collision with the slower moving plow.

To reduce the potential of traffic vehicles colliding with snow removal vehicles, strobe or other high-intensity lighting devices visible to motorists in front and rear, even through blowing snow, are recommended. The Montana Department of Highways uses such a lighting arrangement. Lights revealing plow width are also helpful. The Missouri Highway and Transportation Department uses side clearance lights mounted at cab height that swivel into place.

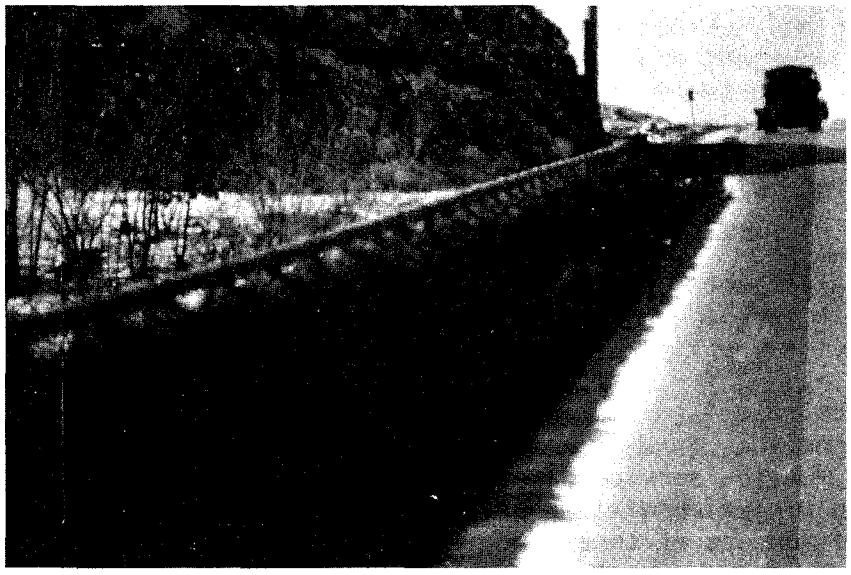
The New York Thruway Authority uses flashing arrow panels on its vehicles to alert motorists. All its plows have been wired to enable arrow panels to be interchanged between vehicles. When not plowing snow, these vehicles provide traffic control during maintenance work.

Motorists need to be better informed about the difficulties in driving, handling, and maneuvering snow removal vehicles and other equipment. Public service announcements educating motorists on how to drive during winter conditions using the theme of "Give'em Room" have been used, but the success of these programs is not yet known.

Rectangular signs with the message "Stay Back 50 Feet" have been successful in alerting motorists approaching snow removal equipment from the rear. The sign's use has been limited to daytime operations in Spencer, Iowa. The signs, constructed of an orange engineering grade of sheeting, have been used on sanders, motor graders, front-end loaders, and sweepers. (The signs are not used on snow plows operating at night from

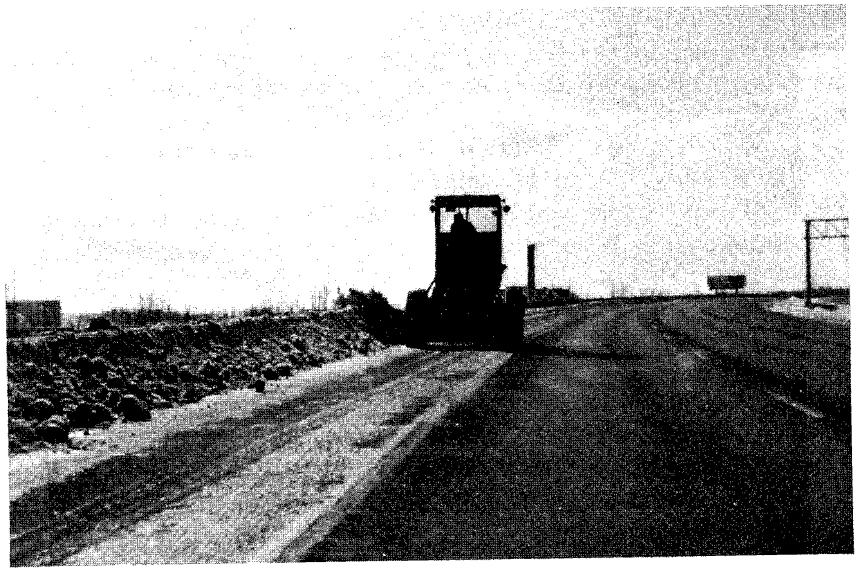


(a)



(b)

Figure 2. Snow accumulations on bridge parapets.



(c)

(d)

Figure 2. Snow accumulations on bridge parapets (concluded).

2 a.m. to 10 a.m.) The signs are most effective on sanders. When sanders are straddling lane lines, vehicles in both lanes stay back from the sander. In four years there have been no accidents or claims involving sanders.

Figure 3 shows hazards that can cause traffic vehicles to collide with snow plows. Figures 3 a and b show a distance and close view of a snow plow during a winging operation. Blowing snow often obscures the plow until drivers are very close to where the plow is operating. Figure 3 c shows a platoon of vehicles following closely behind a snow plow. If the plow slows because of a heavy snow drift, these vehicles may run into the rear of the plow.

d. Intersections and Interchanges

Obscured motorist visibility due to snow piled at intersections and interchanges is the fourth most serious ranked hazard. Snow piled near intersections can affect a motorist's ability to see oncoming vehicles at intersecting roads. These piles of snow also block an oncoming motorist's view of cars at intersections.

In interchange on-ramp areas, piles of snow can hide merging vehicles and vehicles stopped at crossroad intersections. There is a location on the on-ramp where entering vehicles are hidden from and cannot see mainline vehicles. High-speed accidents resulting in severe injuries can occur when these intersecting vehicles collide.

First priority post-snowstorm cleanup areas are unsignalized four-lane intersections, merging areas at on-ramps, off-ramp intersections, and two-lane unsignalized intersections.

Many signalized intersections become flashing signals late at night, thereby operating as unsignalized intersections. Intersections with flashing signals should be cleared of piled snow with the same priority as unsignalized intersections.

Figure 4 shows post-snowstorm cleanup priorities at intersections and interchanges as practiced in Minnesota DOT District 9. The solid portions of the diagrams are the areas susceptible to motorist visibility problems with piled snow.

Figure 5 shows how a driver (a) at an intersection can neither see nor be seen by a motorist (b) on an intersecting road.

Figure 6 shows snow piled (a and b) near the on-ramp mainline merging point. There is a location on the ramp (c) where merging vehicles are hidden from and cannot see mainline vehicles. Severe injuries can result from high-speed collisions.

2. Serious Hazards

The following five hazards were ranked as serious: snow or ice accumulation on guardrail; improper alignment of snow plows; stalled or abandoned vehicles impeding snow removal operations; lack of snow storage

(a)

(b)

(c)

Figure 3. Hazards of vehicles colliding with snow plows.

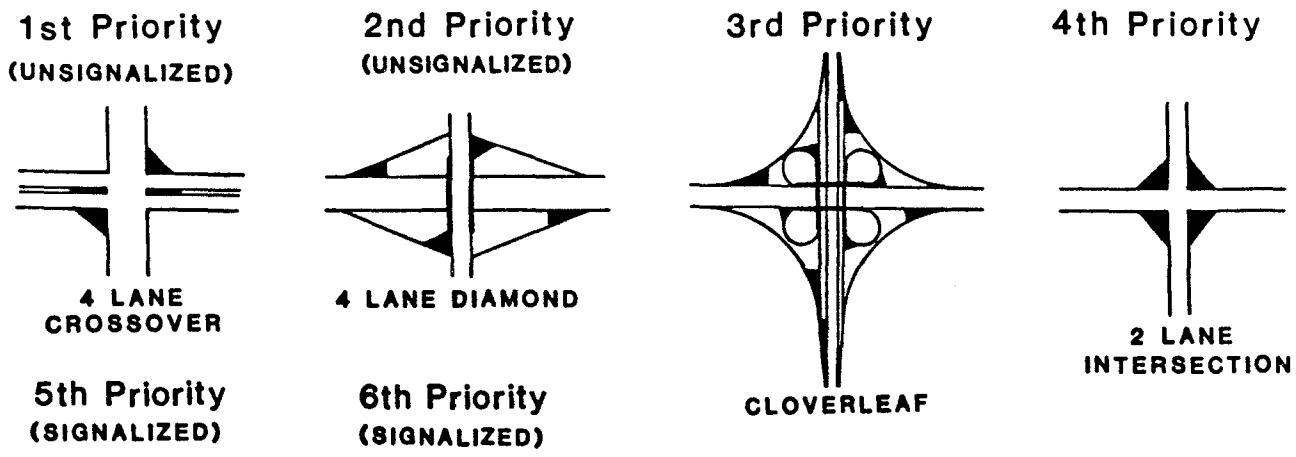
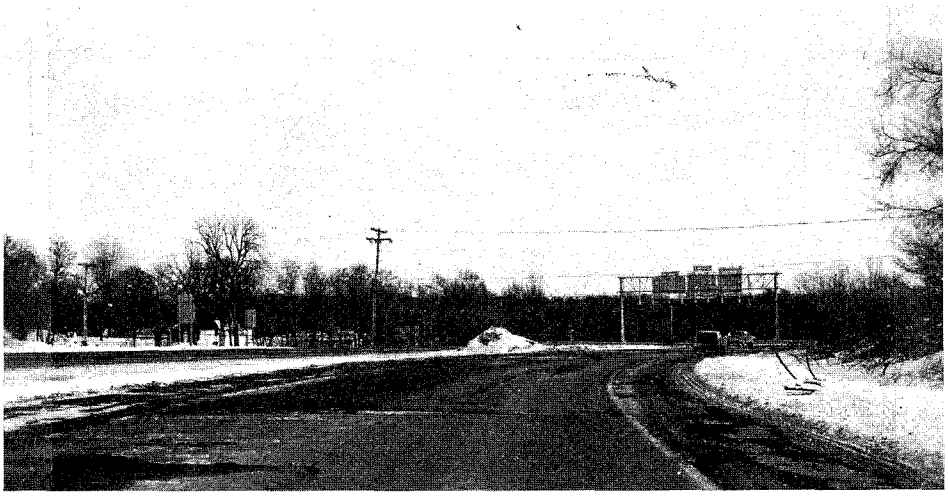


Figure 4. Minnesota cleanup priorities at intersections and interchanges.

(a)

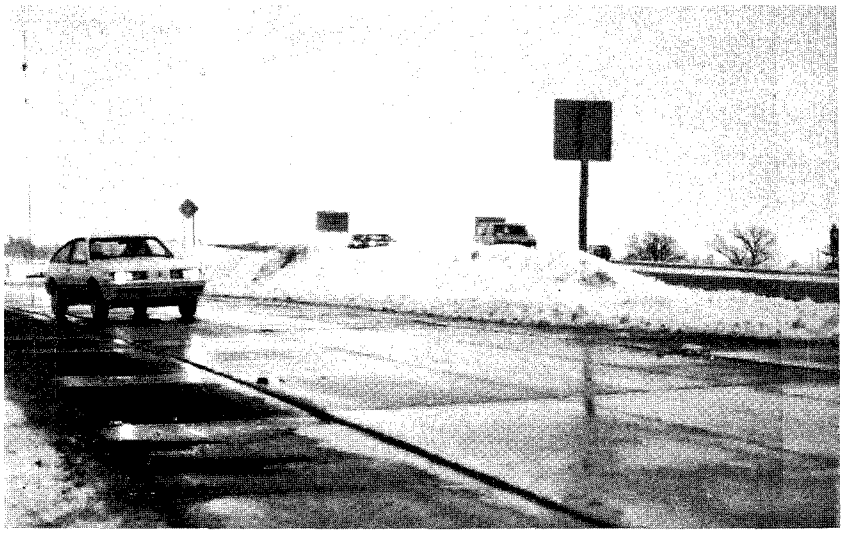
(b)

Figure 5. Obscured visibility at intersections.



(a)

(b)



(c)

Figure 6. Obscured visibility at interchanges.

area at narrow medians, shoulders, and gores; and snow or ice on concrete safety-shaped barriers. These hazards, although serious, should be treated after the hazards rated most serious are remedied.

a. Guardrail

Snow or ice accumulation along guardrail the result of drifting snow or plowing operations, is more of a hazard on freeways than on regular roadways because of the greater length of guardrail, traffic volume, and vehicle speed on freeways. Unsafe conditions include snow drifting on a clear road, possible melting and refreezing of snow, and reduced effectiveness of the guardrail section due to piled snow.

To prevent snow accumulation around guardrail, roadways should be plowed out to the guardrail as soon as possible after roads have been reopened to traffic. To prevent drifting, snow should also be cleared from the shoulder inside guardrail and near the start of guardrail sections. Guide stakes along guardrail sections help snow plow operators locate guardrail even when the rails are completely covered with snow.

b. Snow Plow Alignment

Improper alignment of snow plows can cause traffic following a plowed path to drive off the traveled way. Improper alignment can also decrease usable lane width. This serious hazard arises from the difficulty plows have in negotiating small-radius ramp curves, from plows wandering off the roadway because road edges are not delineated, or from plow operator inattention.

Guide stakes delineate the edge of pavement and help snow plow operators maintain proper plow alignment. Within interchanges, guide stakes should be installed at 50-ft intervals. Guide stakes can be spaced farther apart (200 ft) between interchanges and on rural routes. To avoid annual installation and removal costs, some States prefer to leave guide stakes installed year-round.

c. Stalled or Abandoned Vehicles

Stalled or abandoned vehicles impeding proper emergency snow removal or post-snowstorm cleanup operations are also a serious ranked hazard. Severe snowstorms occurring at rush hour in urban areas create the worst problems because of higher traffic volumes. In rural areas, stalled vehicles can force highway agencies to close roads. Blowing snow is a particular problem in areas where high winds cause drifting. Tractor-trailer trucks that have run off the roadway present the biggest problem because they are difficult to remove.

To help prevent the problem of stalled vehicles during heavy snow, public service announcements should be used to warn people to stay home or to exit the road and sit out the storm. Commercial tow trucks pressed into use for the removal of stranded vehicles should be part of a plan to support snow removal operations. Tow trucks can be called into service by the local police agency.

d. Narrow Medians, Shoulders, and Gore Areas

Lack of snow storage areas at narrow medians, shoulders, and gore areas is another serious ranked hazard, especially when snowfall has been heavy or when storms have occurred in close succession. When piled snow melts it can run off and refreeze, causing localized icing. Piled snow also can obscure vision. It can even collapse onto the roadway during snow-melt.

On multilane highways, to prevent snow accumulation in narrow medians where there is less than 20 ft (6.1m) of storage width or concrete median barriers, the snow should be plowed in tandem from the left shoulder all the way across the roadway to the right. Otherwise, snow will have to be loaded into trucks and hauled away.

Wing plows should be used to create extra storage area on shoulders. In gore areas a motor grader or front-end loader should be used to remove snow. In gore areas, sand and salt on bare pavement can act like ballbearings causing vehicles to skid and to strike signs and other appurtenances. Power sweepers are needed to clean gore areas.

e. Safety-shaped Barrier

Snow and ice piled against roadside or median concrete safety-shaped barriers, especially in areas of frequent and heavy snowfall, is another serious hazard. Urban areas are the most critical. As with bridge parapets and rails, snow piled at two-thirds the height of the barrier changes its shape and creates a vehicle ramping hazard. The hazard is compounded in areas where vehicles can strike barriers at angles greater than 15 degrees, such as on the inside of curves and in wide medians. The side of the barrier facing the sun may be clear of snow, but the shaded northern face, which is hidden from the sun, may contain packed snow.

Normal plowing procedures will remove snow from the lower face of a safety-shaped barrier but will not remove the packed snow that forms a ramp on the upper face. A raised plow blade may be able to pull snow from the upper face of safety-shaped barriers.

Freezing rain on top of an existing snow ramp creates a frozen surface that is especially hazardous.

In Brown County, Wisconsin, a rubber blade attachment aids in clearing snow away from barriers. The rubber plow attachment was designed to sculpt snow out from safety-shaped barriers. Attachments can be made for left and right sides of snow plows. Such an attachment, which is 1-1/2 in (3.8 cm) thick and mounts against the snow plow blade, costs Brown County about $250 and will last two to three years if used properly. Brown County also uses metal attachments on snow blowers to remove snow from safety-shaped barriers. The rubber plow blade attachment is described in appendix C.

3. Important Hazards

Several snow and ice accumulation hazards ranked as important are also present during post-snowstorm cleanup operations. These hazards, which do not require immediate attention except where obvious problems exist, are snow covered drains, culverts, and channels; snow or ice windrows; shallow cut areas; at-grade railroad crossings; pavement obstructions such as curbed and raised areas; obscured highway signs; and snow-covered impact attenuators.

a. Drains, Culverts, and Channels

The accumulation of snow, ice, or debris at drains, culverts, and channels when snow-melt backs up onto the pavement and creates pools of water which can refreeze. Heavy rains that freeze before an impending snowstorm increase the hazard.

Arrows painted on barriers, parapets, or pavement indicating the location of drains will aid in locating drains when they are covered by snow. The New York Thruway Authority marks drain locations and even gives the distance from the edgeline to the drain.

When plowing bridges, drains should be checked to see that they are clear. Clogged drains can be treated with salt but may require hand-cleaning.

Drainage problems at culverts are common in areas with a deep frost depth where ice remains in the culvert. In the spring, melting snow and rain can build up on the roadway and refreeze into slippery spots. Ice can be melted using a steam generator.

Channels and ditches blocked with plowed snow can cause snow-melt to run onto the pavement. Drainage channels that have a history of snow and water backup should be cleared of drifted or accumulated snow in anticipation of thawing weather. A backhoe or hydraulic excavator such as a "Grad-All" can be used. A dump truck may be needed to haul snow.

Snow or ice windrows along the edge of pavement prevent water from running off the pavement, especially in hilly areas. Openings should be made in the windrow to permit drainage of water from the road.

b. Snow or Ice Windrows

Snow or ice windrow buildup at entrance and exit ramps and at intersections is another important hazard which presents an unexpected obstacle to motorists. The hazard, created when a windrow blocks a motorist's path, is usually a temporary condition during plowing operations.

Windrows can be prevented from forming by adjusting plow speed and mold board angle to obtain sufficient snow cast.

To remove windrows, plows operating singly should start plowing from the left and continue around the interchange until snow and windrows have been moved all the way to the right.

If more than one plow is used, plowing activities should be coordinated so that the second plow is in tandem behind the first on both the mainline and ramps.

c. Shallow Cut Areas

Snow or ice accumulation in shallow cut areas is another important ranked hazard. Lack of snow storage area causes snow to blow and drift across the roadway. Blowing snow impedes vision and snow drifts can be struck by motorists. Blowing and drifting are aggravated by successive snowstorms that occur over a short period of time. Roads built perpendicular to the usual wind direction also have definite drifting problems.

Remedies include installing snow fences, winging back and benching snow drifts, using a blower when a shallow cut is full of snow, and loading and hauling away snow. A backup vehicle is needed to alert approaching motorists that roadside cleanup is in process.

d. At-Grade Railroad Crossings

Snow or ice pushed onto at-grade railroad crossings is another important hazard which affects roads other than freeways. Once snow, ice, or aggregate gets into flanges or rails, it is difficult to remove and can cause train derailments.

High-volume urban traffic carries snow slush and debris onto tracks. To alleviate the hazard, the plow should be emptied along the shoulder in advance of an at-grade railroad crossing.

Approaches to crossings should be treated to prevent slippery conditions, but chemicals must not be spread on the track area itself. Plow operators must use extreme care when working around railroad tracks because the extra length of their vehicle and the noise of their operation can prevent their hearing an approaching train. Adjusting the angle of the plow so that it is not parallel to that of the railroad track will prevent the plow blade from dropping into the track channels. Also, snow should not be plowed from overhead bridges onto railroad tracks.

e. Pavement Obstructions

Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and covers that may inhibit snow and ice removal are important hazards but they do not pose much of a problem from either safety or cleanup standpoints. In general, these hazards should receive priority treatment only at locations where there have been safety or cleanup problems in the past.

Such obstructions, especially at channelized areas, can prevent complete snow and ice removal. Snow from these obstructions should be removed before it has a chance to melt, spread, and refreeze onto adjacent pavements.

f. Obscured Highway Signs

In areas of heavy snowfall and drifting compounded by high winds, snow obscuring highway signs is another important hazard. Snow thrown by plows can also adhere to signs. An unsafe condition exists when motorists cannot see a sign legend, especially warning and regulatory signs.

Signposts can be struck to shake the snow loose. Fortunately, snow adhering to signs usually melts and slides off when the sun comes out. Where drifting covers signs, the area should be dug back to clear the signs, especially those in critical areas.

g. Impact Attenuators

Still another important hazard is snow or ice accumulation on impact attenuators. The attenuator may become jammed with snow or ice from emergency snow removal operations. An out-of-control vehicle can climb snow-covered attenuators and strike the object behind the attenuator. Impact attenuators operate well under winter conditions, but care should be taken to see that snow and ice accumulation does not hinder operations. If attenuators are used at hazardous or high accident locations, higher priority treatments should be applied.

To avoid cracking sand barrels during snow cleanup, the snow should be removed carefully with a plow or other equipment. When filling sand barrels, a 20 to 25 percent mixture of salt should be added to the sand to prevent it from freezing.

4. Special Hazard

a. Truck Escape Ramps

Windrows of snow across the approach to truck escape ramps and frozen arrestor bed material pose a special hazard. In mountainous areas with sustained grades, there is the potential for runaway trucks. Truck escape ramps are designed to stop these vehicles safely. In the winter, however, a hazardous situation develops if ramp approaches have not been adequately cleared of snow. During emergency snow removal, windrows of snow left at entrances to escape ramps form barriers that can cause runaway trucks to become airborne. Accident reports from Colorado revealed that runaway truck accidents were made severe by windrows of snow left on shoulders and by snow left across escape ramp entrances.

Approaches to truck escape ramps should be clearly defined by snow plows so that runaway trucks have a clear entrance to the arrestor bed. Colorado uses small tractors to clear a smooth path to the arrestor bed.

The arrestor bed itself becomes less effective in slowing trucks if melted snow and ice refreeze. If aggregate is contaminated with fine material, water from snow-melt will bond the aggregate together and a frozen condition will result. The arrestor bed aggregate must be broken up to greater depth to allow the arrestor bed to function. In Colorado, the arrestor bed is cleared of snow and then the crusty surfaces are broken up using small tractors with rear-mounted fork attachments.

5. Hazard Remedy Table

Remedies for the hazards discussed in this chapter are given in table 2. Maintenance engineers developing emergency snow removal and post-snowstorm cleanup priorities will find table 2 a useful guide that references hazards and remedies. The remedies are divided into two categories: those associated with emergency snow removal, and those to be accomplished during post-snowstorm cleanup activities.

The most desirable "remedies" are those that keep a hazard from being created. Many of the remedies associated with emergency snow removal are of this type and are very desirable. For example, on bridges, pushing snow to the right using plows in tandem is an emergency snow removal procedure that will keep ramps of snow from forming along bridge parapets. If not removed then, snow along barriers should be removed during cleanup. However, this snow ramp may harden first and create a more hazardous condition.

Remedies associated with post-snowstorm cleanup activities are presented in order of increasing difficulty or cost. Remedies received the following ratings in ascending order of difficulty:

Rating 1 - Accomplished with existing procedures, equipment, and manpower;

Rating 2 - Requires some additional work or cost beyond normal procedures; and

Rating 3 - Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

The hazards which have the more difficult cleanup remedies are those that should be corrected by changed procedures during emergency snow removal, if possible.

To use table 2, first locate the snow removal hazard to be corrected. Then see if there is a remedy associated with emergency snow removal procedures that will prevent the situation from becoming a hazard. If the hazard already exists, correct it using one of the remedies associated with post-snowstorm cleanup activities. Try the least difficult or least costly remedy first. Your agency may already have a better way of correcting a particular hazard; if so, use it.

Table 2. Hazard remedies.

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
MOST SERIOUS				
1. Superelevated and sharp curves				
Snow or ice accumulation on high-side shoulder of superelevated ramps and superelevated curves, especially those ramps and curves without reverse shoulder slopes.	On superelevated ramps or curves, plow snow to low side of roadway.	On curves, push or wing snow over high side edge of shoulder line or ditch.	1	
		Apply sand to snow-melt runoff.	1	
		On ramps, remove packed snow with grader or front-end loader	2	Front-end loader or grader
Snow piled in middle of sharp curves reducing sight distance.	Refrain from storing snow on inside of curves.	Wing back snow at points where sight distance is reduced	1	Plow or grader with wing attachment
2. Bridge parapets, rails and curb areas				
Snow or ice accumulation at bridge parapets, rails, and curb areas.	Plow snow to right using tandem plowing.	Plow along bridge to remove parapet snow ramp.	1	
	On short bridges push snow to end of bridge.	Use rubber attachments on edge of plow blade to clean near safety-shape bridge parapets.	2	Rubber attachment
	Apply sand and chemicals to bridge decks.	On long structure load and haul away snow.	3	Snow blowers or front-end loaders and dump trucks. Backup vehicles or traffic control for lane closure.

* Difficulty Rating

1 = Easily accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
MOST SERIOUS (continued)				
Snow plows casting snow from overhead bridges onto adjacent railroads, or properties.	Do not plow snow over bridge rails.	On long bridges, load and haul away snow.	3	Snow blowers, and dump trucks
	Reduce plow speed, straighten mold board, and push snow off short bridges.	Use snow fence or batter boards along bridge rails to keep snow from being cast from bridges.	2	Snow fence or batter boards
3. Plows and other snow removal equipment				
Vehicles colliding with snow plows and other snow removal equipment.	Install high-mounted, high-intensity lights visible from front and rear including side clearance markers to identify plow width.	(same as for emergency snow removal)	2	Special vehicle lights
	Affix signs on rear of plows saying "Stay Back 50 feet"		2	Signs
	Run public information campaign to "Give Them Room."		2	
	Mount flashing arrow panel on snow plow.		3	Flashing arrow panel
	Install attenuators on shadow trucks or plows (where possible).		3	Vehicle-mounted impact attenuators

* Difficulty Rating

1 = Easily accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
MOST SERIOUS (concluded)				
4. Intersections and interchanges				
Reduced sight distance due to snow piled at intersections and interchanges.	Refrain from storing snow at or near intersections, entrance, or exit gores.	Wing snow back at points where motorist sight distance is adversely affected.	1	Plow or grader with wing attachment
		At crossovers, push or wing back snow on upstream side.	1	
		Where snow cannot be winged back, remove and load.	3	Special loading equipment and dump trucks
SERIOUS				
5. Guardrail				
Snow or ice accumulation on guardrail.	Plow full width of roadway to guardrails.	Widen (by winging) out to guardrails.	1	Plow or grader with wing attachment
		Clear snow from shoulder in front of guardrail and near start of guardrail sections to prevent drifting.	1	
6. Snow plow alignment				
Improper alignment of snow plow causing traffic following plowed path to drive off traveled way.		Before snow season begins, set guide stakes 5 ft from edge of the pavement. In interchanges set stakes on right side of ramps at 50-ft intervals.	2	Guide stakes
		Between interchanges, space stakes at 200-ft intervals.	2	Guide stakes

* Difficulty Rating

1 = Easily accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
SERIOUS (continued)				
7. Stalled or abandoned vehicles				
Stalled or abandoned vehicles impeding emergency snow removal and post-snowstorm cleanup operations.	Use public service announcements to encourage drivers to stay home or to exit roadway.	Consider use of commercial tow trucks in emergencies.	2	Tow trucks
		Use care in removing snow around stalled vehicles to keep from damaging vehicles.	1	
		In heavy snow conditions, use large front-end loaders to dig out stalled vehicles.	3	Front-end loaders 5 cubic yards or larger
8. Narrow medians, shoulders, and gore areas				
Lack of snow storage areas at narrow medians, shoulders, and gores.	Plow snow to right in tandem where concrete barrier, fence, or less than 20 ft of storage width in median exists.	Load and haul snow. In gore areas use front-end loaders and load snow into dump trucks.	2	Front-end loaders and dump trucks
		Use power sweepers to clean salt and sand from gore areas.	2	Power sweepers
		In narrow medians use front-end loaders to remove snow from median and haul with dump truck.	3	Front-end loaders and dump trucks
		Close adjacent lane.	3	Traffic control for a lane closure
	Use police or other backup vehicles to prevent motorists from passing convoy.		2	Police or backup vehicle

* Difficulty Rating

1 = Accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
SERIOUS (concluded)				
9. Safety-shaped barrier				
Snow or ice accumulation on safety-shaped barriers.	Do not plow snow against safety-shaped barriers.	Pull snow from barrier face with plow blade.	1	
		Use rubber plow blade attachment to clean barriers.	2	Rubber plow blade attachments.
		In area with insufficent storage room, load and haul away snow.	3	Snow blowers or front-end loaders, and dump trucks
			3	Traffic control for lane closure
IMPORTANT				
10. Drains, culverts, and channels				
Snow or ice accumulation on recessed or indented drains, culverts, and channels.		Mark location of drains with paint spot on the pavement, parapet, or median barrier before winter to aid in locating drains to be cleaned.	1	Spray paint and tape measure
	Treat recessed drains and indented gutter sections with additional salt.	Hand-clean drains.	2	Hand tools

* Difficulty Rating

1 = Accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated With Emergency Snow Removal	Remedies Associated With Cleanup Activities	Difficulty Rating*	Special Equipment Needed
IMPORTANT (continued)				
Snow or ice accumulation on recessed or indented drains, culverts, and channels.		Remove grate and use back-hoe with bucket and dump truck to clean large drains. Hand-clean bottom.	3	Back hoe and dump truck
		Melt ice in culverts with steam.	3	Steam generator
		In anticipation of thawing weather, clear channels and ditches that have snow or water problem history of drifted or accumulated snow.	2	Back hoe or hydraulic excavater such as "Grad-All" and dump truck
Blocked drainage openings where snow-melt forms water pools, such as from windrows at sag vertical curves.	Treat susceptible areas with salt.	In hilly areas with running water, make opening in snow windrow using a motor grader or shovels to keep water off roadway.	2	Motor grader and hand tools
II. Snow or ice windrows				
Snow or ice windrow buildup at exit ramps, on-ramps, and intersections.	Adjust plow speed and mold board angle to obtain sufficient snow cast to prevent windrow buildup. Continue replowing interchanges until all windrows are eliminated. Coordinate plowing so that second plow eliminates windrows.			

* Difficulty Rating

1. Accomplished with existing procedures, equipment and manpower.
2. Requires some additional work or cost beyond normal procedures.
3. Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (continued).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
IMPORTANT (continued)				
12. Shallow cut areas				
Snow or ice accumulation in shallow cut areas.		Install snow fence.	2	Hand tools and supplies
		Wing back snow drifts.	1	Plow or grader with wing attachment and backup vehicle
		Use snow blower when narrow or shallow cut is full of snow.	2	Snow blower
		Load and haul snow.	3	Front-end loader and dump truck
13. At-grade railroad crossings				
Snow or ice accumulation on railroad crossings.	Empty plow along shoulder in advance of crossings to avoid carrying snow or slush onto tracks. Treat approaches but do not spread chemicals in track area. Do not plow snow from overhead bridges down on railroad tracks.	Hand-clean rail flanges (avoid if possible).	3	Hand tools
14. Pavement obstructions				
Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and covers that inhibit snow and ice removal.	Apply additional chemicals to areas. Exercise care in crossing expansion joints.			

* Difficulty Rating

1 = Accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

Table 2. Hazard remedies (concluded).

Snow Removal Hazard	Remedies Associated with Emergency Snow Removal	Remedies Associated with Cleanup Activities	Difficulty Rating*	Special Equipment Needed
IMPORTANT (concluded)				
Snow or ice accumulation on curbs, raised medians, gore areas, and walkways on bridges.	Do not plow snow onto islands or other raised areas.	Load and haul snow.	3	Front-end loaders, and dump trucks
15. Obscured highway signs				
Snow obscuring highway signs (regulatory and warning more important).	Do not cast snow onto signs.			
		Brush signs to knock snow off.	1	Hand tools
		Where drifting snow covers sign, dig back to clear sign.	3	Hand tools
		For signs obstructed in drifted areas and impossible to clear, provide auxiliary signs until original sign is visible.	3	Hand tools
16. Impact attenuators				
Snow or ice accumulation on impact attenuators.	Do not store snow in gore areas. Avoid hitting attenuators with snow plows.	Use pickup truck with plow to clean around attenuators.	2	Pickup truck with plow
SPECIAL				
17. Truck Escape Ramps				
Truck escape ramps with windrows of snow across the approach and frozen arrestor bed material.	Clear approaches to truck escape ramps.	Clear smooth entrance to escape ramp with small tractor.	2	Small tractor
		Clear and work aggregate to keep snow and ice from forming.	2	Small tractor with rear fork attachment.

* Difficulty Rating

1 = Accomplished with existing procedures, equipment and manpower.

2 = Requires some additional work or cost beyond normal procedures.

3 = Difficult to accomplish, requires special equipment or large quantities of manpower to accomplish.

PRIORITIZATION METHOD AND SCENARIOS

The discussion of hazards in the foregoing chapter shows that a number of hazards can be overlooked or created during emergency snow removal operations. Hazards (table 1) were prioritized based on risk, severity, correctability and exposure (see appendix B for definitions). Each maintenance engineer will have post-snowstorm cleanup priorities based on a number of factors related to region of the State, highway features in the maintenance area, weather and time of year, hazardous locations previously identified, and route priorities. A recommendation of this study is that as a minimum each district maintenance unit have a prioritized list of cleanup activities. It is desirable for each maintenance area within a district to have a prioritized list of cleanup activities. This list can be used to schedule post-snowstorm activities at various times in the winter. An example of a district list is the Minnesota District 9 Snow and Ice Removal Plan (appendix D). Note that this is an example and not a model plan.

It is not possible to formulate one post-snowstorm cleanup priority plan that will fit every region of the United States in every situation. A procedure for developing a priority plan, however, is specified in this chapter. The prioritization procedure depends on and utilizes the knowledge of local area maintenance foremen and supervisors. Information on local conditions are provided to the district maintenance engineer, who determines the hazards to be treated first in post-snowstorm cleanup operations.

The prioritization method has four basic steps:

Step 1 - Obtain an Inventory of Existing Features;

Step 2 - Consider Hazards;

Step 3 - Determine Remedies; and

Step 4 - Develop Local Cleanup Priorities

The following discussion details each step in the prioritization method. Scenarios of three typical maintenance units in different areas of the United States are used to illustrate the steps in development of cleanup priorities.

1. Prioritization Method

a. Step 1 - Obtain An Inventory Of Existing Features

Obtaining an inventory of the road system covered in a maintenance unit is necessary in order to determine the quantity of each affected highway feature. The inventory should specify the miles (kilometers) of each type of road covered and the mileage of each route priority type. It is also important to know the number of interchanges, bridges, impact attenuators, and other features that are affected by the hazards. The inventory should also specify locations that have proved to be problems in past winters. Before developing a highway feature inventory, other sources

in the district office should be checked to see if an inventory already exists. Highway features may have been documented with a photo-log system. The planning department may also be able to provide a highway feature inventory.

Inventory information is used by maintenance units in regular planning activities. An example inventory form used in Minnesota is shown in figure 7. This form gives lane miles by priority classification, interchanges, and the number of trucks required and assigned for snow removal operations.

b. Step 2 - Consider Hazards

The second step of the prioritization method involves ranking the hazards identified in the preceding chapter based on the specific maintenance area and on the inventory done in step 1. Special hazards such as truck escape ramps should be ranked only if they are present in the maintenance area.

First, the list of hazards should be reviewed, and those hazards not applicable should be eliminated from consideration. For example, the hazard associated with blocked drainage is a problem only during the spring when there is a large amount of snow-melt and water flowing. In the northern tier of States, this hazard can normally be eliminated until the spring thaw. Another example is the hazard associated with impact attenuators. In an area without impact attenuators, this hazard could obviously be eliminated from consideration.

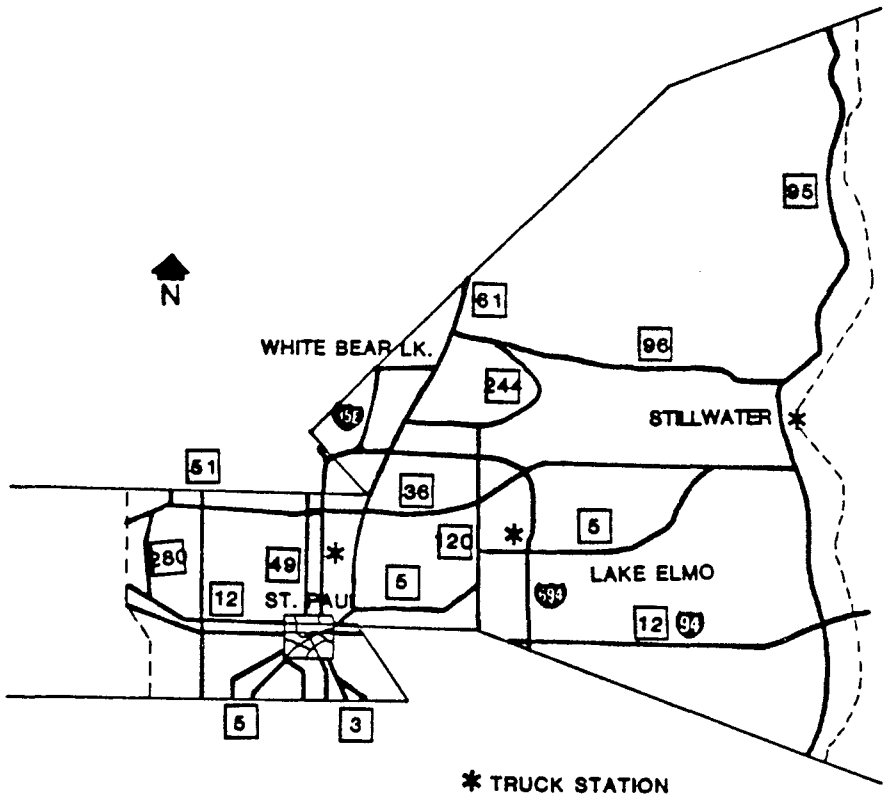
After eliminating inapplicable hazards, the remainder should be ranked based on their overall ranking as discussed in the preceding chapter, maintenance area, time of year, and the frequency of features affected.

Several categories of hazards are presented in table 3. Hazards created by snow storage, snow removal or placement, thawing or melting conditions, truck escape ramps, and other conditions are presented. The hazards are more prevalent when there is a large amount of snowfall, or during certain times of the winter season. Table 3 lists hazards that may create safety problems in a maintenance area. The hazards created by snow storage will rank higher in most areas in the months of December, January, and February. The priority of these hazards should also be higher in areas that normally receive large amounts of snow (greater than 30 inches (76-cm) per year). Hazards could receive higher priorities in other areas or times of year if two or three storms occur or are expected within a one- or two-week period.

The ranked list of hazards should be prepared on a route priority basis; e.g., priority 1 - all lanes with bare pavement before coverage is reduced, priority 2 - right lane of divided roadways with bare wheel paths, priority 3 - two-lane roads with bare wheel paths, before coverage time is reduced.

METRO AREA

SUB-AREAS 4916, 4917, 4918, 4919



METRO AREA SUB-AREAS		WINTER ROUTES	CENTER LINE MILES	LANE MILES: SUPER 30,000	LANE MILES: URBAN 101-30k	LANE MILES: RURAL 2000-10,000	LANE MILES: PRIMARY 800-2000	INTERCHANGES: COMPLEX	INTERCHANGES: SIMPLE	TRUCKS REQUIRED	TRUCKS ★ ASSIGNED
	4916	216	12.6	60.3				12.0	3.0		
		TOTAL	12.6	60.3				12.0	3.0	7.70	8
	4917	226	12.0	84.6				17.5			
		TOTAL	12.0	84.6				17.5		10.35	10
	4918	236	25.1			51.6					
		237	18.8		62.4				3.0		
		238	21.0	39.0	2.8	22.0		1.0			
		TOTAL	64.9	39.0	65.2	73.6		1.0	3.0	7.61	6
	4919	246	25.8	8.6	58.8			2.5	4.5		
		247	14.7	14.2	42.3			1.5			
		248	16.5		19.2	17.6					
		TOTAL	57.0	22.8	120.3	17.6		4.0	4.5	8.83	11
AREA TOTALS			146.5	206.7	185.5	91.2		34.5	10.5	34.49	35

★ CLASS 33 AND 35 TRUCKS

Figure 7. Maintenance area highway inventory form. (29)

Table 3. Categories of hazards.

Hazards Due to Snow Storage

Reduced sight distance due to snow piled at intersections, interchanges, and sharp curves.

Lack of snow storage areas at narrow medians, shoulders, and gores.

Snow or ice accumulation on concrete median barriers.

Snow or ice accumulation on side slopes adjacent to shoulders and in shallow cut areas.

Hazards Created by Snow Removal or Placement

Snow or ice accumulation on highside shoulder of super-elevated ramps and superelevated curves, especially those ramps and curves without reverse shoulder slopes.

Snow or ice accumulation at bridge parapets, rails, and curb areas.

Vehicles colliding with snow plows and other snow removal equipment.

Snow or ice accumulation on guardrail.

Improper alignment of snow plow causing traffic following plowed path to drive off traveled way.

Snow or ice accumulation on safety-shaped barriers.

Snow or ice windrow buildup at exit ramps, on-ramps, and intersections.

Snow or ice accumulation on railroad crossings.

Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and covers that inhibit snow and ice removal.

Snow or ice accumulations at curbs, raised medians, gore areas, and walkways on bridges.

Snow or ice accumulation at impact attenuators.

Snow plows casting snow from overhead bridges onto adjacent roadways, railroads, or properties.

Table 3. Categories of hazards (concluded).

Hazards only During Thaw Conditions
Snow or ice accumulation at recessed or indented drains, culverts, and channels.
Blocked drainage openings where snow-melt forms water pools, such as from windrows at sag vertical curves.
Special Hazards
Snow blocking entrance to truck escape ramps and making frozen arrestor bed material ineffective.
Other Hazards
Stalled or abandoned vehicles impeding emergency snow removal and post-snowstorm cleanup operations.
Snow obscuring highway signs.

c. Step 3 - Determine Remedies

After hazards have been ranked, they are prioritized based on roadway type and the available remedies. Table 2 shows remedies for each identified hazard.

The remedies listed first are those that are associated with emergency snow removal. Changes in snow removal procedures have the potential to eliminate hazards before they are created.

The second column of remedies in table 2 are those that must be accomplished during post-snowstorm cleanup activities. Cleanup remedies are rated according to the difficulty of accomplishing the remedy. Special equipment that has been used to accomplish a remedy is listed in the last column of table 2.

The remedies associated with cleanup activities generally involve changes in priority rather than additional equipment, manpower, or maintenance funds. The goal of the prioritization method is the reduction of hazards with the same or less expenditure.

Many hazards are harder to remedy if they are ignored. If maintenance engineers are aware of them, hazards should be remedied. If not, severe accidents can result.

The goal of this step should be to determine the best remedy for each hazard ranked in step 2 and the difficulty of accomplishing this remedy.

d. Step 4 - Develop Local Cleanup Priorities

The last step in the prioritization process involves consideration of the hazards determined in step 2, remedies determined in step 3, and data on local conditions and weather forecasts. A map of known trouble spots (hot spots), based on previous experience of maintenance engineers and snow patrols, should be prepared and used in developing priorities.

Scheduling of post-snowstorm cleanup activities must be done when emergency snow removal is completed after each snowstorm. The time available to perform cleanup can extend until the next storm begins. Some highway agencies are now working 24 hr per day until cleanup is completed.

The list of hazards (step 2) will change only two or three times in a winter season as snow storage problems become prevalent or when spring thaw begins. Likewise, remedies (step 3), which translate into post-snowstorm cleanup activities, do not change often. The condition of the roadway, however, as determined by road patrols and weather forecasts is constantly changing and must be reconsidered each time post-snowstorm cleanup operations begin. For example, a forecast of warming weather places more importance on clearing drainage features rather than on clearing snow from narrow medians. A forecast of cold weather and additional snow places more importance on clearing medians to allow for additional snow storage.

In order to specify priorities in cleanup, the hazards, remedies, local conditions, and weather forecasts should be considered when emergency snow removal operations are completed and post-snowstorm cleanup activities are beginning.

Recommendations from this study may also be used in planning cleanup activities and specifying activities which should be done on an overtime basis until a hazard is remedied. For example, the Minnesota DOT District 9 policy (appendix D) specifies that bridge parapets and rails should be cleared when snow reaches two-thirds the height of the rail on urban commuter routes. Work is authorized to be done on an overtime basis until the rails are cleared.

Overtime work might also be authorized for regular trouble spots on high priority routes or at isolated locations where a particular hazard has been created, such as limited sight distance at the intersection of a four-lane State highway and a major cross-street. Another condition where overtime work might be authorized for post-snowstorm cleanup is a period when frequent storms makes it impossible to complete high priority activities before another storm is forecast to occur.

Post-snowstorm cleanup activities and the priority order in which they should be remedied in work orders or other documents should be recorded as insurance against liability suits.

2. Prioritization Scenarios

Three scenarios of typical maintenance units in different areas of the United States illustrate the steps in development of cleanup priorities.

a. Maintenance Area 1

This maintenance area is located in a major metropolitan area in the Midwest. The area is in the middle tier of States and receives an average of 20 in (50 cm) of snow per winter. Large snowstorms usually occur about three to five times per winter and average 4 to 8 in (10 to 20 cm) of snow. Frequently snow will melt between storms, even in the middle of the winter. Cold periods with low temperatures below 0 deg F (-18 deg C) have lasted two to three weeks. Weather is variable, with some winters nearly snowless while other winters are as severe as those experienced in northern States.

(1) Step 1 - Obtain an Inventory of Highway Features The area includes about 150 mi (240 km) of streets and highways including 80 mi (130 km) of freeways. There are eight major freeway-to-freeway interchanges in the area and twenty interchanges with nonfreeway facilities. There are 25 impact attenuators located in gores at these interchanges.

A large river borders one side of the maintenance area. There are three freeway bridges and four other long bridges across this river. Two of the freeway bridges were constructed within the last 10 yr and have safety-shaped bridgerails, and the third is an older bridge with parapets.

The freeway in the downtown area is of an older design than circumferential freeways that vary in age from 15 yr to very new construction.

Winter maintenance trouble spots in the past have included left-curving superelevated ramps at major directional interchanges, bridges over the river, and rearend collisions with snow plows.

(2) Step 2 - Consider Hazards Based on the urban character of this maintenance area, the time of year (mid-January) and the lack of highway features, a number of hazards shown in table 3 can be eliminated from consideration. For example, hazards associated with snow storage are not prevalent in this area because of the limited snowfall. So reduced sight distance problems can normally be eliminated. Snow storage problems could become a hazard with the narrow medians in the downtown area. Since there are no truck escape ramps in the area, they can be eliminated from consideration.

The resulting hazard list is shown in table 4. Snow accumulation on bridge parapets is the highest ranked priority due to the occurrence of long river bridges on freeways in the area. All the hazards are also ranked according to route priority.

(3) Step 3 - Determine Remedies Many of the hazards of maintenance area 1 can be remedied by changes in emergency snow removal procedures that keep the hazards from being created. For example, plowing snow to the low side of superelevated ramps and curves will usually remedy the hazard of snow on the high side of superelevated ramps and curves.

For hazards that cannot be eliminated with changes in emergency snow removal procedures, a cleanup remedy should be chosen. If possible the lowest difficulty remedy should be used. For example, the hazard of snow accumulation on bridge parapets should be remedied by plowing near parapets to remove the ramp of snow. If this remedy is ineffective or cannot be used, a more difficult remedy may have to be used such as loading and hauling the snow.

Cleanup remedies for maintenance area 1 are shown in table 5. These remedies are listed in the same order as the hazards listed in table 4.

(4) Step 4 - Develop Local Cleanup Priorities After a 4-in (10-cm) snowstorm, emergency snow procedures were varied to include remedies associated with emergency snow removal. After the storm had subsided and the traveled way was clear, road patrols reported that snow had been pushed from the high side of superelevated ramps and curves. Other remedies including additional devices to prevent rearend collisions with snow plows were also instituted during emergency snow removal operations.

Table 4. Example hazard list maintenance area 1.

Superelevated and sharp curves.

Bridge parapets, railings, and curbed areas.

Vehicles colliding with snow plows or snow removal equipment.

Guardrail.

Improper snow plow alignment.

Narrow medians, shoulders, and gores.

Concrete median barriers.

Impact attenuators.

Snow or ice windrow buildup at exit ramps, on-ramp entrances, and intersections.

Drains, culverts, and channels.

Railroad crossings.

Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and hole covers that may inhibit snow and ice removal.

Table 5. Example remedies maintenance area 1.

Plow near bridgerails or curbs to remove ramp of snow.

Clear snow from shoulder in front of guardrail and near start of guardrail sections.

Set guide stakes at interchanges on right side of ramps to guide snow plows.

Plow near barriers to remove ramp of snow.

Clear entrance ramp gore areas to avoid gore sight distance problems. Clean around impact attenuators.

Mark locations of drains with paint spot on pavement or median barrier to aid in locating drains to be cleaned.

The road patrol did report some ramps of snow along bridgerails, particularly along the north side of east-west rails where the snow ramp was shaded. Also, several gores and on-ramp merge areas had large piles of snow that could hamper the view of merging vehicles.

Based on a forecast of continued clear cold weather with no thawing, the area maintenance engineer specified the list of cleanup activities shown in table 6.

b. Maintenance Area 2

Maintenance area 2 is located in a major metropolitan area in the Northeast. The area is in the northern tier of States and receives an average of 48 in (120 cm) of snow per year. Large snowstorms usually occur four to eight times per year and average 6 to 12 in (15 to 30 cm) of snow. Unbroken cold periods below freezing usually extend from mid-November to the end of March, with few thawing periods.

(1) Step 1 - Obtain An Inventory of Highway Features The area includes 150 mi (240 km) of streets and highway (including nearly 60 mi (100 km) of freeways). There are few long bridges in the area and a total of 25 interchanges, 12 of which are major freeway-to-freeway interchanges. Only ten impact attenuators are located in the interchanges in this area.

Much of the roadway is of older design on restricted right of way. Winter maintenance trouble spots in the past have included snow piled in merging areas and cross-street intersections at interchanges, and lack of snow storage space in medians and shoulders.

(2) Step 2 - Consider Hazards Based on the urban character of this maintenance area and the time of the year (late December), the hazards associated with spring thaw can be eliminated. The truck escape ramp hazard can likewise be eliminated.

The completed hazard list for maintenance area 2 is shown in table 7. Snow accumulation on the high side of superelevated ramps and curves is the highest ranked hazard. Bridge parapets are not ranked so high in this area because of the low number of long bridges. Hazards associated with snow storage rank high in this area due to heavy snows and normally cold conditions.

(3) Step 3 - Determine Remedies Although some of the maintenance area 2 hazards can be corrected by changes in emergency snow removal procedures, there are many hazards that must be remedied by cleanup operations.

Table 6. Example cleanup priorities maintenance area 1

Order of Priority	Cleanup Activity
1	Plow bridge parapets on freeway river bridges to remove snow ramps.
2	Clear gore areas at major interchanges to remove sight obstructions. Clean around impact attenuators.
3	Plow bridge parapets on nonfreeway river bridges to remove snow ramps.
4	Plow near safety-shaped barriers to remove ramps of snow.
5	Clear gore areas at interchanges with non-freeway facilities to remove sight obstructions and clean impact attenuators.

Table 7. Example hazard list maintenance area 2

Superelevated and sharp curves.

Snow piled at intersections, interchanges, and curves.

Vehicles colliding with snow plows and other snow removal equipment.

Snow or ice accumulations at bridge parapets, rails, and curb areas.

Lack of storage areas at narrow medians, shoulders, and gores.

Stalled or abandoned vehicles preventing proper emergency snow removal and cleanup operations.

Snow or ice accumulation on concrete median barriers.

Improper snow plow alignment.

Snow or ice accumulation on guardrail.

Snow or ice windrow buildup at exit ramps, on-ramps, and intersections.

Snow or ice accumulation on impact attenuators.

Snow or ice accumulation on railroad crossings.

Snow or ice accumulation on curbs, raised medians, and gore areas.

Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and covers that inhibit snow and ice removal.

Cleanup remedies for maintenance area 2 are shown in table 8. These remedies are more extensive than those used in maintenance area 1. In many areas of heavy snowfall, winging operations are normally completed immediately after the traveled way is cleared. In locations where storage room is limited, snow may have to be loaded and hauled to remove hazards if easier remedies are not applied after each storm.

(4) Step 4 - Develop Local Cleanup Priorities With 20 in (50 cm) of snow already on the ground, two major storms of 5 and 12 in (13 and 30 cm) hit maintenance area 2 within a four-day period. Between storms, only one eight-hour shift worked on cleanup before the second storm started.

After the second storm, road patrols reported several interchanges where sight distance was greatly reduced due to piled snow in gores and near on-ramp merging areas. Also, most safety-shaped barriers had a ramp of snow over two-thirds their height.

The weather forecast was for three days of cold clear weather and a 70 percent chance of another snowstorm starting on the fourth day.

Based on these reports, the weather forecast, and previously chosen remedies (table 8), the area maintenance engineer specified the list of cleanup activities shown in table 9. Note that overtime work was authorized for winging back snow in areas where sight distance was affected, and for plowing near safety-shaped bridge parapets and barriers where snow was over two-thirds the height of the barrier.

c. Maintenance Area 3

Maintenance area 3 is located in a rural area in the West. The area is about evenly divided between plains and mountains. The area is in the northern tier of States. The plains portion of the area receives an average of 50 in (130 cm) of snow per year. In the mountains, snowfall varies from 50 in to 90 in (130 cm to 230 cm) of snow per year. Large snowstorms occur frequently, especially in the mountains. Unbroken cold periods below freezing usually extend from late October to mid-April. Prevailing winds are from the north and west.

(1) Step 1 - Obtain an Inventory of Highway Features The entire maintenance area has about 250 mi (240 km) of highway including about 120 mi (200 km) of freeways. The roadway mileage is about evenly divided between the plains and the mountains. There are a total of twelve interchanges in the area, but none of these are freeway-to-freeway interchanges. There are no impact attenuators in the area, and only two long bridges on the freeways.

Rural two-lane highways are subject to extensive drifting especially in the plains. In the mountains, roadways are steep and curved and there is extensive guardrail. There are four truck escape ramps in the area.

Table 8. Example remedies maintenance area 2.

Wing snow back at points where sight distance is affected.

Plow near bridge parapets, rails, or curbs to remove snow ramps.

Load and haul snow. In gore areas use front end loaders and load snow into dump trucks. Load and haul snow in areas with insufficent snow storage room.

Plow near median barriers to remove snow ramps.

Widen roadway out to guardrail.

Use pickup truck with plow to clean around impact attenuators.

Load and remove snow from raised curbed areas.

Table 9. Example cleanup priorities maintenance area 2.

Order of Priority	Cleanup Activity
1	Wing snow back at interchange areas where sight distance is affected. (Use overtime as necessary.)
2	Plow near bridge parapets on freeways to remove bottom portion of ramps of snow. (Use overtime as necessary.)
3	Load and haul snow in gore areas.
4	Load and haul snow from narrow medians on freeways.
5	Wing snow back on non-freeway Priority 1 routes.
6	Widen roadways out to guardrail.
7	Clean around impact attenuators to remove ramps of snow.
8	Load and remove snow from raised curb areas.

(2) Step 2 - Consider Hazards Based on the rural character of this area and the time of year (mid February), several hazards can be eliminated from consideration. For example, there are no impact attenuators and very little concrete median barrier. There are no areas with pavement obstructions such as raised islands or rumble strips. The hazards associated with spring thaw can also be eliminated.

The hazard list for maintenance area 3 is shown in table 10. Several differences are apparent between this rural area list and the list for the urban areas in maintenance areas 1 and 2. Hazards associated with truck escape ramps are also included in the list.

(3) Step 3 - Determine Remedies Remedies for maintenance area 3 are shown in table 11. The remedies are listed in the same order as the hazards listed in table 10. Winging or widening out may be included as part of the emergency snow removal in some maintenance areas. Cleanup activities listed are extensive and some, such as cleanup at truck escape ramps, may involve special equipment such as a small tractor with a rear fork attachment.

(4) Step 4 - Develop Local Cleanup Priorities A storm with high winds and up to 15 in (40 cm) of snow hit maintenance area 3 causing extensive drifting. Because of the drifting and large amount of snow, emergency snow removal was prolonged and a great deal of winging back was accomplished in many areas.

Road patrols reported most areas in front of guardrail and on the high side of superelevated curves clear. Stalled vehicles were moved out of the way of snow removal operations.

The weather forecast called for cold clear weather for several days and little chance for additional snowfall.

Based on these conditions, the area maintenance engineer specified the cleanup priorities as shown in table 12. The list shown is for the entire maintenance area, but separate cleanup priorities could have been specified for the mountain and plains areas.

Table 10. Example hazard list maintenance area 3.

Superelevated and sharp curves.

Guardrail.

Vehicles colliding with snow plows.

Stalled vehicles preventing proper emergency snow removal and cleanup operations.

Truck escape ramps with windrows of snow across approach and frozen arrestor bed material.

Shallow cut areas.

Bridge parapets, rails, and curbed areas.

Snow piled at intersections, interchanges, and curves.

Improper snow plow alignment.

Narrow medians, shoulders, and gores.

Snow or ice windrow buildup at exit ramps, on-ramps, and intersections.

Railroad crossings.

Snow obscuring highway signs.

Table 11. Example remedies maintenance area 3.

On curves, push or wing snow over high side edge of shoulder line or ditch.

Widen out to guardrail.

Use care in removing snow around stalled vehicles to keep from damaging vehicles. Use commercial tow trucks in emergencies.

Clear smooth entrance to truck escape ramps.

Clear and work aggregate in truck arrestor beds to keep snow and ice from forming.

Wing back snow drifts.

Use snow blowers when narrow or shallow cut is full of snow.

Plow near bridge parapets to remove bottom ramps of snow.

Do not plow down on railroad tracks from overhead bridges.

Wing back snow at points where sight distance is affected.

Where drifting snow covers signs, dig back to clear sign. Warning and regulatory signs are most critical.

Table 12. Example cleanup priorities maintenance area 3.

Order of Priority	Cleanup Activity
1	Wing back snow drifts.
2	Blow snow out of narrow or shallow cuts where drifting is problem.
3	Clear smooth entrance to truck escape ramps.
4	Work (scarify) aggregate in truck arrestor beds to keep snow and ice from forming a solid crust.
5	Plow near bridge parapets to remove ramps of snow.
6	Wing back snow at points where sight distance is affected.
7	Where drifting snow covers signs, dig back to clear sign.

CONCLUSIONS

The objectives of the study were to determine the nature and extent of hazards due to snow removal practices, identify locations where snow removal might cause safety hazards, and to determine solutions to these hazards. Several possible remedies are presented in Recommendations.

- Seven State highway agencies were interviewed by telephone to determine their post-snowstorm cleanup priorities and potentially hazardous winter maintenance conditions. All the agencies address, in their written snow and ice control procedures, the necessity for post-snowstorm cleanup operations and specify highway features to be treated during this activity. Most of the State highway agencies do not explicitly prioritize their post-snowstorm cleanup operations.

- Ranking by the project staff of seventeen hazards based on the product of the ratings risk, severity, correctability, and exposure produced three distinct groupings. The hazards ranked most serious are: snow or ice accumulation on superelevated curves, snow or ice accumulation on bridge rails, vehicles colliding with snow removal equipment, and reduced sight distance due to piled snow at curves, intersections, and interchanges.

- Snow or ice accumulation on the highside shoulder of superelevated ramps and superelevated curves without reverse shoulder slopes or rounded shoulder cross sections is a hazardous condition that ranks highest amoung the most serious hazards.

- Snow or ice accumulation at bridge rails, parapets, or curb areas is a most serious hazard tied for second place in the priority ranking.

- Vehicles colliding with snow plows or other snow removal equipment occurs because of lack of visibility created by swirling snow and/or the stop-and-go driving of snow plows. It is a most serious hazard and is tied for second in the priority ranking.

- Reduced sight distance due to piled snow at curves, intersections, and interchanges is ranked fourth among the most serious hazards.

- The hazards ranked serious are: snow on guardrail; improper alignment of snow plows; stalled or abandoned vehicles blocking cleanup operations; lack of snow storage area at narrow medians, shoulders, or gores; and snow on safety-shaped barriers. These hazards are serious, but may be treated with a lower priority than the most serious hazards. Some of these hazards ranked higher on one or two types of facilities, and therefore, their treatment priority should be related to the facility type.

- The hazards ranked important are: snow accumulation at drains culverts, and channels; snow windrow buildups at exit ramps or on-ramps; snow accumulation on side slopes near shallow cuts; snow or ice accumulation on railroad crossings; pavement obstructions that inhibit snow removal; snow accumulation at impact attenuators; and snow obscuring highway signs. These hazards should not receive priority treatment during cleanup operations except where obvious problems exist.

- In mountainous areas, where there is the potential for runaway trucks, winter maintenance is needed at truck escape ramp entrances to clear a smooth entrance to the ramp and on the arrestor bed to keep an ice crust from forming.

- Although most of the hazards have similar rankings across the four facility types, some ranked differently on a specific type of facility. Snow or ice accumulation at safety-shaped barriers rated much higher in urban areas. Snow or ice accumulation at side slopes adjacent to shoulders with shallow cuts ranked highest on non-interstate rural routes. Snow or ice accumulation on impact attenuators or attenuator mechanisms jammed with snow or ice ranked highest on urban interstate routes.

- In general, cleanup is more hazardous in urban areas because there is more traffic, more features requiring cleanup, more critical areas such as superelevated ramps and curves, and more interchanges. Cleanup in urban areas requires careful planning and scheduling so that activities coincide with off-peak traffic periods.

- Cleanup hazards are aggravated by frequent snowstorms. Storms spaced in close succession without the opportunity for significant melting make it difficult to recognize potential hazards and to schedule, plan, and conduct cleanup activities.

- The monthly average number of accidents in winter is higher than the average in nonwinter months because more accidents occur on snow-covered roads. Although the percentage of fatal and injury accidents is lower during winter months, fatal and injury rates (accidents/traffic volume) increase because of reduced traffic volume during snowstorms.

- Remedies are available for each identified hazard (see table 2). Many of the remedies can be accomplished without additional cost to the State highway agency.

- The most desirable "remedies" are those procedures that keep a hazard from being created. Many of the remedies that are most costly and time-consuming are associated with hazards that have been left untreated until a major problem develops; for example, narrow medians that are packed with snow.

- Ramps of snow are more likely to be a long-term problem on the north side of east-west barriers where sunlight is not available to help melt snow.

RECOMMENDATIONS

Hazards identified in the study can be remedied by a number of means, including: changes in snow removal operations, revised cleanup priorities, and new equipment designed to handle cleanup functions. Most of the solutions to safety problems lie in the areas of management and procedures rather than in technological advances.

1. Remedies should be applied in the following order: first, apply remedies associated with emergency snow removal to keep hazards from being created; second, apply low difficulty post-snowstorm cleanup remedies that do not require additional manpower or equipment; and third, when necessary, apply more difficult remedies that require special equipment and additional manpower.

2. State highway agencies should formalize post-snowstorm cleanup priorities so that these operations are performed in a specific manner. The prioritization method presented in this report is recommended.

3. Additional research should be conducted on an effective means to communicate to drivers the hazards associated with driving too close to snow plows. This research should investigate way to increase plow visibility, to reduce the amount of snow blowing around plows, to educate motorists as to snow plow operations to reduce accidents, and to use vehicle-mounted attenuators for plows.

4. State highway agencies should make arrangements to have reserve or backup forces and equipment in case of severe storms. Contractors' equipment that is not being used in the winter can be rented during emergencies. Weather conditions and equipment needs can be monitored at the headquarters office. Manpower and equipment are shifted to the areas of the State that need the most help.

5. States should subscribe to a weather radar service to determine in advance if weather conditions are going to hamper cleanup operations. Close monitoring of advance weather forecasts for periods of three days would enable maintenance personnel to know if weather conditions are going to promote melting or whether post-snowstorm cleanup must include storage room for additional snow.

6. Snow removal equipment should be designed to meet the needs of cleanup at highway features. Some changes involve simple fixes that result in high payoffs in terms of improving the efficiency of cleanup operations. For example, in Brown County, Wisconsin, a rubber snow plow blade attachment and a metal snow blower attachment for clearing snow from safety-shaped barriers were developed.

7. When storms occurring in quick succession create problems with snow removal or cleanup operations, post-snowstorm cleanup should be given a higher priority. In this mode, cleanup should be conducted on an over-time basis or additional forces should be mobilized.

8. Neighboring highway agencies should work together to alleviate common problems on shared routes. Although highway agency responsibility for maintenance activities ends at jurisdictional boundaries, motorists expect clean and safe highways without regard to boundary lines. At interchanges, reciprocal arrangements can be made, for example, so that the responsibility to remove snow from the interchange is not split between jurisdictions.

APPENDIX A - LITERATURE REVIEW

The literature search sought to identify research on safety problems, snow removal, ice control, and cleanup operations. A computerized literature search of Transportation Research Information Service (TRIS) and National Technical Information Service (NTIS) abstracts was conducted. The search produced 126 TRIS and 36 NTIS reference abstracts. Each abstract was reviewed with respect to its value to this study and was rated as being of potential, secondary, or negligible value. Most of the relevant references dealt with winter maintenance activities. Few dealt with traffic accidents except for studies of safety in relation to studded tires or effects of salt. Little in the literature dealt with winter safety relating to highway appurtenances or features.

References identified through the computerized literature search, the Midwest Research Institute (MRI) library and Linda Hall Library of Science and Technology were obtained and reviewed. References unknown to the project team were also provided by the Contracting Officer's Technical Representative (COTR). Information pertaining to winter safety problems in relation to emergency snow removal, ice control, and cleanup operations was extracted.

This appendix presents the detailed review of literature sources and is presented in two sections: (1) emergency snow removal and post-snowstorm cleanup and (2) winter traffic safety.

1. Emergency Snow Removal and Post-Snowstorm Cleanup

The California Department of Transportation (Caltrans) conducted a study to identify ways of reducing direct and indirect costs relating to its snow and ice control program. (1) These costs include: headquarters and district staff and facilities related to snow removal, excess equipment and personnel, cost of purchasing activities, cost of materials, delivery costs, stockpiling costs, application of materials and plowing, storage facilities for snow equipment, location of maintenance facilities, legal expenses, road condition information, environmental concerns, and damage to roads and structures. Using information from its maintenance management system, Caltrans identified thirteen major winter maintenance functions. These were ranked in order of importance considering the amount of effort expended on them. In order of descending importance, the major snow and ice control functions include: plowing, maintenance of snow equipment, ice patrol, rock patrol, applying abrasives, chain control, widening, applying salt, cleanup, maintenance of snow poles, production and transportation of abrasives, avalanche control, and snow fencing.

The safety function of safety-shaped barriers is negated when snow accumulates against them. A device for cleaning snow from along safety-shaped barriers was developed by the Brown County, Wisconsin, Department of Transportation. (2) The rubber device is shaped to fit the face of the barrier and attaches to a conventional plow blade. The publication describing the device and its specifications is presented in appendix C - Snow Removal from Safety Barriers.

A National Cooperative Highway Research Program (NCHRP) study was undertaken to identify factors affecting snow removal, to study the problems and current procedures for solution of these problems, and to suggest improved techniques for snow removal and ice control in interchange areas. (3, 4) In the first of two volumes, factors, problems, and techniques influencing the efficency of snow removal and ice control are summarized in two categories, physical and operational. The physical factors include appurtenances, turnarounds, crossovers, connections for equipment routes, snow storage areas, and adjacent development. The operational factors include organization and training, maintenance yard location, procedures, equipment, materials, traffic, jurisdictional boundaries, and climatic conditions.

Volume 2 is a manual for use in planning and conducting snow removal and ice control maintenance operations in highway interchange areas. (4) The information and guidelines are intended for use in designing highway interchanges to reduce the need for snow removal and to accommodate snow removal and ice control operations when required. Volume 2 (4) consists primarily of illustrations and diagrams and a minimum amount of text. The two main chapters are Maintenance Operations and Interchange Design. Included in Maintenance Operations are plowing, chemical spreading, and cleanup. Pictures and text in the cleanup operations section describe removing heavy snowfalls, winging back shoulders, and plows backing up ramps. The photographs and text in the interchange design section are beneficial in identifying potential problem areas relating to snow removal and cleanup at interchanges.

A publication by the Salt Institute is intended to provide highway winter maintenance personnel with procedures and techniques for combatting winter storms. (5) It is intended to help the snowfighter give the public the most effective snow and ice control program possible and, therefore, safe winter roads at the least overall cost. One section of the publication talks about trouble spots such as bridges, intersections, ramps, hills, and curves. It also discusses giving interchanges special attention, keeping large trucks out of the way, and deicing grates on bridges. In the area of cleanup after the storm, recommendations are made to wing back shoulders; clear structures and haul snow from critical areas; remove windrows; and clear snow from overhead bridges, raised medians, barrier walls, traffic dividers, and drains.

A Sioux City, Iowa report, stresses the importance of preparedness in an effective snow control program. (6) The key element is preparedness in weather forecasting. Other key elements are the ability to assign equipment and personnel from other departments or private contractors to snow-control operations when necessary, the ability to modify shift schedules to assure 24-hour snow control operations, and a maintenance program to assure that at least 80 percent of all street equipment is operational at all times. That city has been divided into four major snow and ice removal areas, with a supervisor assigned to each area. Personnel are expected to be familiar with their areas and with any possible hazards. Snow removal from the central business district (CBD) usually receives priority for snow removal. Snow hauling operations in the CBD are generally done at night to avoid heavy traffic. Emergency calls regarding snow are usually routed through the police to help eliminate false calls. When snow and ice conditions warrant, the chief of police is authorized to

announce that nonemergency travel is not recommended. Generally, the four materials used for snow and ice control are straight salt, salt mixed with sand and calcium chloride, salt mixed with sand or other abrasives, or straight sand. "Chain" crews perform simple vehicle fitting, allowing the central garage to concentrate on vehicular repair in order to keep vehicles on the road.

The paper by the Director of Public Works of a Minnesota city discusses the challenge of removing snow in a small city.(7) The paper discusses planning, flexibility, review, and revision. Areas of snow removal discussed include mainline streets, cul-de-sacs, sidewalks, vehicles parked on the street, and cleanup operations. The author states that the most efficent cleanup operations are done by assigning a fleet of vehicles to specific locations rather than having them travel their complete routes looking for cleanup activities. One of the prime cleanup areas is pushing back or "topping off" existing snow banks. Two road graders with wing plows following in tandem are used for this operation; performed during off-peak snow removal periods. It was stated that it takes approximately seven to nine days to complete this type of operation. Fortunately, it is required only once or twice during any snow removal season. The final area of cleanup is to clear the more than 2,000 fire hydrants in the city. The maintenance division installs 3-ft wire whips with red flags to each fire hydrant to help identify their location until they can be cleared by maintenance personnel during off-peak periods.

A paper from a county in Minnesota discusses snow and ice removal as an emergency operation that takes precedence over all other maintenance activities. (8) When snow falls, the measure of response and expenditure depends on a combination of variables including traffic volumes, snowfall accumulation rate, moisture content, and wind velocity. Snow removal activities are complicated by the time of day, day of week, and availability of equipment and personnel. Guidelines were developed to respond to an average snowfall of 4 to 6 in occurring over a period of six to eight hours. Priorities are assigned according to traffic volumes. A description of the type of equipment used is presented. Loading and hauling snow is done as little as possible because of the expense involved in the operation.

Each county road is assigned as urban (more than 7,500 vehicles average daily traffic (ADT)), rural (1,000 to 7,500 ADT) or secondary (under 1,000 ADT).(8) Final service level determination also considers other important characteristics, including speed limits and roadway design. Continuity of service levels is maintained to logical terminus points (major intersections) along a route.

On urban routes the goal is to achieve "clear pavement" within five hours of the storm's end. (8) Because most of the urban routes are four lanes or more, it is beneficial to have two or more units working in tandem. This provides fast service and prevents traffic from pulling snow back onto plowed lanes.

While clear pavement is still the goal on rural routes, 24 hours rather than five are allocated for achieving normal driving conditions after a storm.(8) Some intermittent compacted snow with appropriate sanding is acceptable.

On secondary roads, which generally have little or no curb and few intersections, intermittent clear pavement in wheel tracks with sanded hills, curves, and intersections is the level of service objective. (8)

One article recounts the snow and ice control operations associated with the Buffalo, New York, blizzard of January 1985. (9) Buffalo Mayor James D. Griffin was forced to impose a driving ban from Monday, January 21, to Friday, January 25. He also personally supervised the snow control operations. National Guard units and their equipment as well as State and private contractors were used. Overall sentiment regarding the ban was favorable. Mayor Griffin stated he would do it again if necessary, and also recommended that other communities opt for bans on driving to decrease the amount of time necessary to remove the snow for severe conditions such as this.

A workshop sponsored by the Transportation Research Board (TRB) Committee on Safety Appurtenances and the American Association of State Highway and Transportation Officials (AASHTO) Highway Sub-committee on Maintenance was convened to discuss operational and maintenance problems with highway safety appurtenances. (10) The objectives of the meeting were to identify problems, assess solutions to problems, and identify research needs. Examination emphasized the cost of installation, repair and normal maintenance; the difficulty of maintenance due to special parts, equipment, labor, deterioration, etc.; and factors adversely affecting operation of the appurtenances such as the accumulation of snow or sand and unusual site requirements. Problems identified that directly affect snow removal and cleanup include low guardrail, snow accumulation or debris adjacent to barriers, and snowdrifts adjacent to W-beam guardrail.

For each problem area, a suggested solution was presented. (10) For low guardrail, it was suggested to remove and reset the rail or use adjustable blockouts that would allow adjustments. For snow or debris against guardrail it was suggested to remove snow as quickly as possible; have snow plows as near the barrier face as possible; and use cable barrier if acceptable. For snowdrift adjacent to W-beam guardrail, it was suggested that a guardrail be designed to satisfy safety requirements and minimize the snowdrift problem.

A study concerning tort liability of maintenance activities in Pennsylvania was conducted. (11) Discussions of specific cases between attorneys and engineers yielded strategies relating to maintenance operations. Among the elements addressed in the discussions was the category of icy spots and snow removal. It was recommended that a program be set up to identify locations that ice up frequently and determine probable causes and the appropriate remedial action. It was suggested that winter night patrols be utilized to identify trouble spots during non-working hours. Procedures to be followed were presented and included using two-way radios for notification of icy spots, preparing a list of known trouble spots, recording the notification and correction times, anticipating likely periods when icy spots could occur, and being prepared to correct them. It was also recommended that snow be cleared from bridge parapets to prevent vehicle ramping.

One report on the proceedings of the APWA Iowa Snow Conference reports one speaker recommending the establishment of snow removal policies to combat liability lawsuits. (12) The snow removal policy should include a record system documenting snow removal activities, providing the local media with information on policies specifying which streets will be given priority treatment, and establishing a formal complaint procedure. It is also important that policies be flexible to make adjustments for uncontrollable factors.

One article on the reduction of tort liability recommends identifying roadway sites which ice up frequently and correcting this hazardous situation prior to winter. (13) Also, for those locations which ice up frequently and are caused by illegal driveways or run-off from adjacent parcels of land, property owners should be confronted about the problem, and if they fail to correct it the agency's legal counsel should pursue appropriate legal action. A third suggestion is to erect "Watch for Ice" signs near icy spots which cannot be corrected. Also suggested is documenting complaints of hazardous conditions.

In a paper discussing the effects of highway design standards on snow and ice control operation, the author states that despite the many technological improvements of modern highways, there are new projects being designed and constructed with insufficient recognition of maintenance especially those involving snow and ice control. (14) The hazards created by snow melt are explored and remedies suggested to either eliminate or substantially alleviate these and other problems to provide for greater safety and reduce maintenance costs. Areas discussed include bridges, channelized intersections, median crossovers, medians and gore areas, interchanges, and appurtenances. The author states that, in general, urban projects require particular attention since these are the areas where special problems arise because of right-of-way restrictions and complexity of design and high traffic volumes. Maintenance activities should be considered in planning, design, and construction.

An FHWA report discusses the integration of maintenance needs into preconstruction procedures (15). Areas discussed include maintenance considerations in highway planning, roadway design, and bridge design. The report includes many diagrams and covers all aspects of maintenance including snow and ice removal. In addition to helping highway planners and designers efficiently design the maintenance functions into highway facilities, the diagrams are useful for identifying potential problem areas relating to snow removal and cleanup operations.

One report describes Denver, Colorado's snow control plan. (16) Because of severe blizzards late in 1982 and 1983, Denver realized the inadequacy of its old snow control plan, and developed a new plan. The Early Warning System (EWS) goes into effect anytime a possibility exists for severe snowfall. The two components of the EWS are Homebase, a central office for compiling and sending information to coordinate crews and equipment, and the Office of Emergency Preparedness, which becomes the Emergency Operations Center (EOC), for the duration of a severe storm. Raw data comes into the EOC, and a computer system helps analyze details, make cost projections, and prepare snow control alternatives. Denver has categorized its streets into three priorities, with highest priority given to major thoroughfares essential for emergency vehicles. Equipment operators first

clear all high priority streets before they begin clearing streets of the next highest priority. Work crews are often consulted due to their invaluable experience and perspective. In a real crisis, other city departments and private contractors are available to help in the snow control process.

An article from "Technotes" contains a checklist of recommendations for an effective snow control program. (17) Pre-winter planning recommendations include planning routes so trucks are at storage facilities when the trucks are nearly empty, keeping routes for emergency vehicles clear, having employees make trial runs of their routes before winter, pinpointing drains and waterways that must be opened after every storm, marking structures hidden from a plow, training plow operators, checking equipment, loading and testing all spreaders, inventorying and ordering equipment and spare parts, stockpiling deicing material, properly storing materials, releasing details of snow control plans to other departments, and contracting a forecasting firm. Winter operations recommendations include setting plow angles correctly, using optimum gear ratio when plowing, beginning deicing as soon as snow starts falling, plowing areas where snow drifts occur, clearing drains and catch basins, removing windrows from the sides of bridges, clearing snow from raised medians, preparing trucks immediately to go back out when they return, using fencing to prevent drifts, and performing preventive maintenance on equipment every 100 hours of service during the winter months.

Another article from Public Works provides a checklist for snow control operations. (18) Items on the list include planning of plowing routes for trucks so that they are near storage facilities when almost empty of deicing material, keeping emergency routes open at all times, adequate employee training and drilling, good preventive maintenance practices, stockpiling deicing material before winter, access to reliable forecasting, clearing drains and catch basins to allow melting snow and ice to run off, and removing windrows from the sides of bridges.

A University of Kansas Transportation Center newsletter gives several recommendations on snow control operations. (19) These include removing snowdrifts before they harden, clearing drains and catch basins to allow ice and melting snow to runoff, clearing snow from traffic dividers and barrier walls, removing snow from sharp corners and bends, removing windrows on the sides of bridges to prevent drifting, clearing snow from raised medians to prevent drifting, and using fencing to prevent drifts and reduce the need for snow control.

One report describes St. Paul, Minnesota's snow and ice control plan. (20) When four or more inches of snow falls, St. Paul declares a snow emergency. The five stages of a snow emergency are predicting the snowfall and calling truck drivers to work, sanding/salting streets according to a prioritized list, plowing of high speed/high volume streets after two inches of snow has fallen, declaring a full snow emergency after four inces of snowfall and operating three full shifts for plowing, and after plowing is completed, beginning cleanup and widening operations. Sanding continues in slippery areas, and snow removal continues on an as- needed basis. During a snow emergency, parking is banned from streets scheduled to be plowed, with violators being fined.

Minneapolis, St. Paul's sister city, uses the same basic system but with some variations. (20) During a snow emergency, parking is prohibited on odd or even sides of residential streets. The next day, the opposite side of the streets are plowed. The author, however, feels that the extra work and lack of parking created by this procedure do not justify its use.

One National Safety Council report gives several recommendations in the various areas of snow removal and ice control. (21) Problems encountered in snow removal and ice control are limited visibility accentuated by glare and reduced light; amount of snow; variable temperatures, wind velocities, traffic maintenance and control during the operation, and reduced traction experienced by all vehicles. To deal with these factors, planning is recommended to develop the most economical and safest method for snow removal and ice control. Factors to be considered are traffic patterns, availability of personnel and equipment, scheduling of shifts, and proper assignments and priorities. Personnel should also be trained and tested in the performance of their tasks. Equipment should be selected to meet road designs and minimize hazards. The equipment should undergo a preventive maintenance program, with critical parts inspected on a periodic basis. To aid the maintenance effort, thorough maintenance records should be kept on each piece of equipment. Spare parts should also be stockpiled. Diagrams of various configurations of snow plows working in tandem are given in the report as well as guidelines for prioritizing roadways and dealing with interchanges. Planning for the application of chemicals should be performed to ensure efficient use of chemicals and equipment. Tables for the application rates of salt and chemicals are given in the report. Plans should be flexible enough, however, to allow for changes and adjustments as needed.

A snow and ice control bulletin from Connecticut describes its post-storm snow and ice control activities. (22) These activities include clearing snow from shoulders, removing snow and slush from drainage structures, cleaning sidewalks, clearing bridges of snow, clearing impact attenuators, clearing intersections, sanding isolated icy areas, returning traffic signals from a flashing mode to their normal mode, and washing all equipment within 24-hours after a storm to reduce the possibility of corrosion.

An article in Better Roads gives guidelines for the proper application and usage of salt. (23) Finer salt promotes faster melting action and provides an alternative to prewetting with liquid calcium chloride. Personnel training, adequate equipment, calibration of spreaders, and use of automatic controls help keep salt use to a minimum. Timing is important, and placing salt early means reducing the amount of salt needed. While salt is often mixed with abrasives to reduce material cost, straight salt requires less spring cleanup than salt with abrasives. Equipment should be cleaned between storms to protect it from corrosion. Also included in the article are three tables for the application rates of salt, and one table for the pounds of ice melted per pound of salt applied.

Another article in Public Roads discusses the use of oil and gas field brines as road deicing agents. (24) Brines are a waste product of oil and gas and highway agencies could acquire brines as a deicing agent at minimal

cost. Tests have shown that brines, in general, are effective as deicers. Natural brines resulted in less portland cement concrete surface deterioration than did conventional chloride deicers. Mixed results were obtained when comparing the corrosion effects of brines and chlorides on steel. Brines also have been shown to be particularly effective deicers at low temperatures.

Still another article in Public Works recommends using wetted salt in lieu of rock salt for the clearing of ice and snow off roadways. (25) Wetted salt is rock salt that is wetted with liquid calcium chloride. This wetting improves deicing action, and therefore reduces the amount of salt needed. Wetting results in lower chemical costs, fewer applications, and reduced maintenance and manpower. Delivery methods include wetting the salt as it is passing through the spreader mechanism. Several communities have successfully tested wetted salt and some now use it extensively. Using liquid calcium instead of the dry form reduces handling expenses and elimates many problems associated with the transportation of dry chemicals.

Public Works also examines the monetary savings associated with using snowblowers instead of front-end loaders for snow removal operations. (26) It was determined that the cost of snow removal using a front-end loader is $1.62 per compacted cubic yard, whereas the cost using a snowblower is only $0.39 per compacted cubic yard. Taking into account, trucking efficiency, capital investment, depreciation, fuel, and maintenance costs, a 28 percent savings is realized when using snowblowers instead of front-end loaders for snow removal. It is important to note that this article did not address the fact that a front-end loader is a more versatile piece of equipment with a myriad of applications, which makes it a more economically attractive alternative than examined in the above comparison.

A study conducted in New Hampshire showed that given the proper snow removal equipment snow can be plowed at speeds up to 60 mi/h. (27) This decreases the speed differential between snowplows and the motoring public, thereby reducing the chance of accidents.

One report recounts testing done by Henke Manufacturing on some of its snowplow designs. (28) Testing was conducted using a water trough at the Chrysler Chelsea Proving Grounds in Chelsea, Michigan, and was for testing load carrying, displacement, and discharge characteristics. The most important factors, the tests showed, were varying the cutting edge layback angle and properly blending the moldboard radii to gather the load and carry it away to discharge. At the ideal angle, snow and ice are scraped from the road surface with a minimum of effort. Too steep an angle requires excessive power. Also, proper cutting edge layback angle and moldboard intercepting radii prevented water from curbing back into the plow path and did not produce flurries over the top of the moldboard and onto the truck windshield. Chrysler and Henke are exploring the possibilities of modifying the facility at Chelsea to facilitate the further testing of snowplows.

One article reports the improvement that the Arlington County, Virginia, Department of Public Works has realized in snow control through the use of a trunked radio system. (29) Previously, several county departments shared the same channel. Because of the cacophony on the radio, many vehicle operators were turning their radios off. This meant a

lack of communication among members of crews. Maintenance personnel also were turning off their radios, which meant that operators had to go to phones to make service calls if their vehicle was down. Even with radios on, it was extremely difficult to break into the system and talk, because of the extensive numbers of users. The county has assigned the operation, maintenance, and other divisions their own channels. All channels still go to one control center, which allows different divisions to work with each other more efficiently. After four winter snowstorms and four icestorms that year, the radios were popular with snow control personnel. Maintenance crews now respond much quicker to breakdown calls and the number of personnel required for snow control operations has been reduced due to the use of the new radios.

An FHWA technical advisory recommends that each State have a planned snow removal program. (30) Components of this program include a weather condition reporting system, coordination of equipment and materials, the use of chemicals as deicers, and scheduled patroling of roadways to locate unsafe conditions during and after a storm. Environmental issues should be considered when dealing with the chemical deicers.

One article in Public Works reports that the New York State Department of Transportation uses plastic fencing on overpass railings to prevent snow and debris that is plowed off the bridge decks from falling on the roadways below. (31)

An FHWA report on snow and ice control operations recommends leaving snow poles in place year-round because of the cost of removing and reinstalling the posts. (32) It was also noted that maintenance personnel, in an attempt to do the best job possible, tend to clean roads better than is necessary, unless they are constantly supervised. Under certain conditions, the use of rental snow removal equipment with operators can reduce operating costs.

An FHWA study in Colorado on truck escape ramp aggregates contains the following conclusions (33):

- All ramps in Colorado are prone to freezing four to six months of the year
- All ramps lacked proper drainage
- Aggregate distribution was variable for all ramps
- During extreme cold, smaller aggregate freezes to a degree of stiffness greater than larger aggregate freezes.
- Aggregate gradation depends on maintenance addition of new material and contamination due to run-off water from the adjacent mountain
- Contamination increases with an increase in depth of the arrestor beds

In summary, the literature review of snow removal and post-snowstorm cleanup activities revealed the following:

- Preplanning helps a snow control program be more effective.
- Cleanup is of moderate importance in relation to other snow removal activities.
- Guidelines exist for snow removal and cleanup.
- One new technique for cleaning snow from safety-shape barriers was learned.
- Techniques for snow removal of interchanges are known.
- Changes that can be incorporated into newly designed highways to improve winter maintenance are known.
- The use of private contractors during snow emergencies can be both economical and effective in snow control.
- Driving bans during and after severe snowstorms can help expedite the snow and ice control process.
- Most cities give their CBD's and emergency vehicle routes top priority in their snow and ice control programs.
- Wetted salt is generally cheaper to use and more effective than rock salt, especially at lower temperatures.
- Finer salt promotes faster melting and is an alternative to prewetted salt.
- Straight salt (without abrasives) requires less spring cleanup than salt with abrasives.
- Oil and gas field brines are effective and economical alternatives to conventional chloride deicers.
- Snowblowers are more economical to use than front-end loaders in snow and ice control operations.
- Snow plow blades placed at the proper orientation require less horsepower to be pushed and do the most effective job of cleaning.
- For small-scale operations, multirole vehicles tend to be more economical than specialized snow control equipment.
- An effective communication system among work personnel can help expedite snow and ice control and maintenance operations.
- Snow control personnel, unless closely supervised, tend to clear roadways of snow and ice better than is necessary.

- Snow control personnel should be trained and made familiar with assigned tasks.

- Truck escape ramp entrances should be plowed during emergency snow removal operations so the entrance is clear and well-defined.

- Truck escape ramp arrestor material should be broken-up so that it remains loose and unfrozen.

2. Winter Traffic Safety

A 1957 study sponsored by the Pennsylvania Turnpike Commission determined human and physical factors as causes of Turnpike accidents. (34) State police accident reports were coded and analyzed to furnish indications of trends and data for special studies. A special study of driver behavior and accident locations was undertaken to isolate possible combinations of driver behavior, weather, and road characteristics which contributed to winter condition accidents. Analysis by three-month periods of the various physical and driver behavior factors showed "inadequate coping with road conditions" involved in a higher percentage of passenger-car-responsible than in truck-responsible accidents, especially in the fall and winter quarters. Many of these accidents occurred on snowy or icy highways after the weather had cleared. Car drivers were responsible for six times more accidents than were truck drivers, apparently showing the value of greater training and experience of the professional drivers. In relation to this study, results indicate that passenger car drivers do not understand the hazards of snow/or ice covered roads as well as truck drivers.

Comparison of accidents under various winter road conditions showed that accidents on icy highways were two to nine times more numerous than expected, but on dry highways were less than expected. (34) Accident rates of mountain area segments were several times higher than those of other areas. Much higher passenger car accident rates on icy highways were found in each area.

An overall analysis was made based on total vehicle mileage and estimated proportion of the total highway represented by curve and grade combinations. (34) Results indicated that on icy highways, "straight-and-level" and "right-curve, down-grade" were higher than expected but not "left-curve, down-grade," taking the highway as a whole.

By manner of collision, fixed object, rear-end, sideswipe, other, and crossover accidents were the most frequent in that order under icy road conditions. (34) All the manners of collision were higher than expected when taking exposure into account. According to judgments made by investigating officers, estimates of initial speeds in accidents indicate that drivers had slowed under winter road conditions but still misjudged or reacted in such a way as to get into trouble. These results indicated the importance of immediate cindering and clearing of ice and snow from the highway, and of warnings to unwary motorists during and after the storm that roadway conditions are still slippery.

A state-of-the-art study of the economic impact of highway snow and ice control was conducted. [35] Eleven States participated in this study which covered maintenance, traffic safety, environment, roadway damage, vehicle corrosion, structural deterioration, and economic analysis. The report presents a summary of safety aspects as learned from other literature sources. Results of the studies showed that different conclusions may be drawn from similar studies. In relation to salting snow-covered highways, data showed an increase in accidents during winter months and a less substantial increase in accidents in townships using deicing salts. However, a larger study reported therein, including injury and fatal crashes occurring on snow- or ice-covered roads, showed that there was no change in the proportion of snow- or ice-related accidents despite an increase in salt usage.

It was noted that while a more severe winter will generally result in a higher incident of accidents, this relationship does not always apply to specific storms. [35] It was stated that traffic volume may sharply decrease in heavy storms but accident rates will usually be significantly higher. The total number of accidents on urban streets rises sharply during and immediately following winter storms. During a snowstorm, accidents occurring on wet pavements were more severe (33 percent injuries and fatalities) than those occurring on snow-covered roads (10 percent injuries). In comparison, 20 percent of the accidents occurring during clear weather on dry pavements resulted in injuries. These results indicate that the driving public is aware of the danger on snowy and icy streets and slows down but is not sufficiently aware of the potential for skidding or hydroplaning on wet pavements.

A study reported accidents on roads with snow or ice. [35] Roadways with average daily traffic (ADT) below 100 vehicles per day had very few accidents, which implies that accidents should not be considered a factor in snow and ice removal policies on low-ADT routes. On roadways between 800 and 2,000 ADT, accidents were within an acceptable range. However, an exception to this was where the weekend ADT was greater than 2,000. Approximately 50 percent of the accidents occurred during that time. The primary function of those routes was to service skiing areas.

Another study reported that 35 percent of all rural traffic accidents occurred while roads were covered with snow and ice, although there were less than seven full days that winter when roads were snow covered. [35]

Another study reported that a snowfall of less then 1/2 in (1 cm) brings an accident rate ten times that for the same hours when the pavements are dry. [35]

A continuation of the above work was presented in a report and three papers. [36, 37, 38, and 39] National accidents rates were presented for snow-belt States, non-snow-belt States, and Utah. The results indicated that fatal accident rates on rural highways were approximately twice as high as for urban highways. Seemingly contradictory results indicated that for injuries this trend reversed; urban injury rates were significantly higher than rural. Fatal accident rates were slightly lower for snow belt States than for non-snow-belt States. Injury accident rates were reversed; snow belt States exhibited a notably higher rate than for non-snow-belt States. A study concluded that both property damage and personal injury

accident rates were highest for snow-packed roads, lower for wet pavements, and lowest for dry roads. Analysis showed that accident rates for property damage and injury accidents increase significantly during a storm. It was stated that if Utah was typical of other snow-belt States, then a careful analysis of their accident data would also indicate higher accident rates during a storm, together with increased social consequences of higher injury and possibly death rates. The previous statement was said to be presented to contradict the common assumption that personal injury accidents decrease during storms. In relation to traffic volumes, no storm characteristics showed significant correlations with volume reductions. Traffic volumes under snow conditions appeared to be strongly influenced by trip purpose and anticipated pavement condition while en route.

A synthesis of safety research related to traffic control elements reported the effects of adverse environmental conditions. (40) Results of studies reported above were included in this publication. Another study analyzed accidents on the six days with the most snow in Great Britian during 1969 and 1970. Results showed a significant increase in fatalities and injuries ranging from 4 to 52 percent. These significant increases were for five of the six snow days. Accident rate increases ranging from 13 to 78 percent were also significant.

A study conducted for the Pennsylvania Department of Transportation sought to learn whether winter maintenance manpower was being used effectively. (41) The objectives of the study were to determine the cost effectivness of single-and dual-shift staffing during winter months, identify maintenance activities which were not snow related and which could be performed during cold weather, estimate the amounts of work which could be accomplished with single and dual shifts, and ascertain optimum winter staffing patterns. It was determined that dual shift operation, for at least part of the winter season, could be more economical than single shift operations in some districts and counties. Results of an accident analysis indicated that there were no statistically significant relationships between accident rates for single or dual shifts. It was concluded that weather variability was likely to mask any relationships that could exist between shift patterns and accident rates. It was felt that the sample size in relation to the range of variables was too small for reliable analysis.

Relative to other fixed object accidents, those involving crash cushions occur with much less frequency. Four studies presented the results of accidents involving crash cushions. (42, 43, 44, 45) A study to determine time periods for inspection and repair of highway safety hardware stated that the annual pecentage of accidents involving crash cushions ranged from 3.2 to 22.6 percent, with an average of 11 percent. (42) The report concluded that the more successful a safety device becomes, the more difficult it is to evaluate due to under-reporting of accidents.

A study in Kentucky reported that crash cushions performed properly in over 80 percent of the collisions. (43) It was also reported that the most common location for crash cushion accidents (43 percent) are gore areas, where various types of crash cushions are used.

A Texas study concluded that crash cushions reduce fatalities by 78 percent and injuries by 27 percent. (44) It was noted that when crash cushions are placed near the roadway they themselves constitute an additional obstacle in the roadway environment. Therefore, the installation of crash cushions should be expected to increase accident rates somewhat, thereby reducing the savings in death and injuries. However, it was thought that the increase in overall accidents rates is small.

A Rhode Island report on impact attenuation devices stated that there were 52 accidents in the one-year study period covering 1981 and 1982. (45) Some of these accidents would not have occurred if not for the impact devices because the vehicles would have slipped by the protruding attenuator. However, those that would have happened without attenuators would have resulted in a higher death-personal injury experience. It was also noted that 25 of the 52 accidents were recorded during the five-month period from November through March, which can be considered the winter period. These months were characterized by darkness and wet and slippery pavement.

It was reported that the fifty installations were comprised of the following types of attenuators: twenty sand barrels, nineteen HI-DRO Cushion Cell Sandwich Units, eight HI-DRO Cushion Cell Cluster Units, and three GREAT System Units. (45) As far as the winter performance of these barriers was concerned, the agency frequently inspected the units and no trace of freezing of any component part was found. (This corresponds to comments received from highway agencies during interviews. Frozen sand-filled barrels may have been a problem in the past, but it appears no longer to be a problem as long as the barrels are adequately sealed to prevent water from entering.) In a conversation with the author, it was learned that sand barrel attenuators are susceptible to damage from snow plows. Snow plows nicking the plastic drums may crack them causing the contents of the drum to spill out onto the roadway. As part of its research and evaluation process, the agency has developed an electronic hit recorder to indicate when an impact attenuator has been struck by a vehicle.

Studies conducted by the FHWA in Wisconsin show that the frequency of accidents at impact attenuators is greater during winter months, but that the severity of the accidents is less. (46, 47) Salt is added to sand in the attenuators in a 20 to 25 percent proportion to eliminate freezing.

The Wisconsin Accident Facts book shows that while more accidents occur during the winter months, the severity of the accidents is less, resulting in fewer fatalities than in the warm months. (48)

An article in Better Roads reports that Norway experienced a 50 percent increase in traffic accidents in the winter due to snow and ice conditions and long hours of darkness. (49) Pedestrians are ten times more likely to fall on sidewalks during winter. Improved road friction from salt and aggregates result in higher speeds and more accidents. It was concluded that drivers prefer reduced travel time to improved safety.

An analysis of 1983 and 1984 accidents from the Fatal Accident Reporting System (FARS) shows that accidents are more likely to occur on

bridges with wet, snow, and ice conditions (22 percent) than accidents at other locations (18 percent). (50) Wet snow and ice conditions on bridges also produce more fatalities (23 percent) when compared to fatalities at other locations' fatalities involving wet, snow and ice conditions (18 percent). Accidents from the FARS data base are presented below:

1983-84 FARS Accidents and Fatalities by First Harmful Event

	Accidents		Fatalities	
	Bridge	Other	Bridge	Other
Total	1380	76,227	1542	85,304
Wet, Snow, and Ice	309 (22%)	13,885 (18%)	356 (23%)	15,683 (18%)

One report recounts a fatal accident involving a Mercury Cougar hitting a concrete barrier, which had snow piled against it at the time. (51) It was concluded that the vehicle ramped the barrier due to the barrier shape (GM) and also due to the snow piled against the barrier, as well as the high impact speed and angle.

Winter safety of truck escape ramps is a concern in mountainous States. Snow in front of escape ramp entrances is an unneeded hazard faced by runaway trucks. There are six basic types of escape ramps in the United States: sandpile, gravity ramp, ascending grade arrestor bed, horizontal-grade arrestor bed, descending grade arrestor bed, and roadside arrestor bed. (33)

Colorado has seven gravity and two descending truck escape ramps. (52) A gravity ramp consists of a hard-surfaced lane that is on an ascending grade. Aggregate is used to keep vehicles from rolling backward. Descending grade escape ramps decelerate with arresting material such as gravel. (33)

The Colorado Department of Highways conducted a study of truck escape ramp incidents (usages) for large truck combinations. (53) Approximately 60 percent experienced brake failure of some kind. With regard to incidents, 36 percent occurred in summer, 29 percent in spring, 24 percent in fall, and 11 percent in winter.

Truck escape ramp incidents for the years 1983 and 1984 were analyzed to determine if the presence of snow on the ramp had an effect on the severity of incidents. Of the 131 reported incidents, 17 percent occurred with snow on the ramp. These occurred from November through May. Escape ramp incidents involving snow resulted in an 18 percent injury rate while those without snow had a 6 percent rate.

Truck volume data were available by escape ramp but not by month of year. Analysis by truck volume showed that escape ramp incident rates ranged from 2 to 55 incidents per 100,000 trucks.

The results show that most incidents occur in summer months due to brake problems. Fewest incidents occur in winter months. However, trucks striking snowbanks at escape ramp entrances become airborne, which aggravates injury severity. Frozen arrestor bed aggregate also allows trucks to roll backward after forward motion has stopped.

In summary, the literature review of winter traffic safety revealed the following:

- The number of accidents is greater during the winter months, but the severity of the accidents is less.
- The frequency of injury accidents is less for snow-covered roads compared to dry or wet roads, but in terms of rates, injury accident rates increase on snow-covered roads, because traffic volumes decrease with storm severity.
- Accidents are more likely to occur on bridges during ice and snow surface conditions and are more severe when compared to accidents at other locations under the same conditions.
- Drivers tend to prefer reduced travel time to improved safety during winter conditions.
- Passenger car drivers have a more difficult time coping with winter road conditions than truck drivers.
- In terms of snow and ice road conditions, fixed object, rear-end, and sideswipe are the most frequent manners of collision.
- Roads with an average daily traffic of over 2,000 vehicles per day experience a proportionally higher snow- and ice-related accident rate than lower volume roads.
- Increased salt usage may not decrease the winter accident rate.
- Impact attenuators reduce the severity of accidents and perform well under winter conditions.
- Truck escape ramp incidents were more severe for occupants of runaway trucks when ramp entrances were covered by snow banks which caused runaway trucks to become airborne.
- Frozen arrestor bed material allowed trucks to roll backward after forward motion was stopped and resulted in injuries.

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APPENDIX B - HAZARD RANKING METHODOLOGY

The ranking of snow-related safety hazards to be addressed during emergency snow removal and post-snowstorm cleanup operations is presented in this appendix. A list of potential hazards was developed from the literature review and personal experience of the three staff engineers, including the principal investigator. The list was first refined to nineteen potential hazards after telephone interviews of State and district maintenance engineers and supervisors and later refined to seventeen hazards listed in table 1.

Hazards were ranked by highway class (urban freeway, rural freeway, urban nonfreeway and rural nonfreeway) because emergency snow removal is done on a route priority basis. The purpose of ranking hazards was to determine the order, by highway class, in which hazards should be remedied by State highway agency maintenance departments. To calculate hazard rankings, the project staff utilized hazard definitions, results of the literature review, State accident statistics, and results of the telephone interviews. Information learned in the telephone interviews was the most important because it was based on the experience of fifteen individuals from seven highway agencies in different regions of the United States. Highway agency engineers reviewed and commented on the rankings presented in this project's Interim Report. (44)

The ranking of snow-related hazards used estimates of risk, severity, correctability, and exposure and was based on a ranking procedure previously used by the University of Tennessee in the FHWA project, "Identification of Traffic Management Problems in Work Zones." (34) The risk, severity, correctability, and exposure of each hazard were rated on a scale of 0 to 5 as defined below.

Risk: Risk is a measure of the probability that an accident will occur if the problem is not corrected. The rating was based on the level of traffic and the probability that traffic will encroach on the feature affected. Rating:

0-2 indicates the facilities affected have low traffic volumes, and the features affected are seldom encroached upon.

2-3 indicates a low traffic condition with a high encroachment rate or a high traffic condition with low a encroachment rate.

3-4 indicates the traffic level is moderate or high and the encroachment rate is low or moderate.

4-5 indicates high traffic volumes and encroachment rates and that the problem affects each vehicle in the traveled way.

Severity: Severity is the seriousness of an accident if one occurs because the problem was not corrected. Rating:

0 indicates that no hazard would result if the accident occurred or in other words that the problem would not cause reportable accidents.

2 or below that indicates minor property damage accidents would result from the problem.

2-3 indicates that accidents occurring would cause moderate property damage but few injuries.

3-4 indicates that accidents occurring would cause extensive property damage and frequent injuries.

4-5 indicates that accidents caused by the problem would cause extensive property damage and almost always result in injuries, including some fatalities.

Correctability: Correctability is a rating of how easy the hazard is to correct. It was based on the cost, personnel, time, and equipment required to correct the problem. Rating:

0 indicates an uncorrectable problem.

2 or below indicates problems that are costly and time-consuming to correct.

2-3 indicates a problem that can be corrected with moderate cost or that special equipment is probably needed.

3-4 indicates a problem that can be corrected at moderate cost or with additional work beyond normal procedures.

5 indicates that the problem is correctable with little additional cost or manpower using established procedures and equipment.

Exposure: Exposure is the rating of how often the winter driving public faces the problem. The rating was based on the frequency that the feature occurs, time or distance that the problem exists, or a combination of these features. Rating:

0 indicates that the winter driving public is not exposed to the feature affected.

2 or below indicates that the feature occurs only infrequently or that the problem exists for a short time or over a limited distance.

2-3 indicates a low exposure over a moderate or extended period of time or distance or a moderate exposure that exists for a short period of time or only at a spot location.

3-4 indicates either a high exposure or an extended period of time or long distance of roadway.

4-5 indicates both a high exposure and an extended period of time and/or a long distance.

For each hazard, a composite rating was calculated using the product of risk, severity, correctability and exposure (RSCE). The composite product (RSCE score) reflects the relative overall savings that might be realized by remedying the hazard at all locations within a highway class. The composite products (RSCE scores) were then rank-ordered as presented in Table 13. These rankings are used to determine local post-snowstorm cleanup priorities by highway class.

After the prioritized ranking by highway class was completed, a combined overall rank was calculated to determine how hazards ranked without regard to highway class. For each hazard, the four highway-class composite products were summed. The sums were then rank-ordered to produce the overall ranking of hazards. (65) These rankings give the overall importance of the hazards and the priority that the hazards should be corrected.

Table 13 lists the nineteen original hazards, the overall rank of each hazard, and the rank of hazards for each highway class, as well as the composite score which equals the product of risk, severity, correctability, and exposure. The composite scores ranged from 252 to 0. Since freeways do not normally have at-grade railroad crossings, a total of eighteen hazards were ranked for urban freeways and eighteen for rural freeways. Nineteen hazards were ranked for urban nonfreeways and nineteen for rural nonfreeways. Hazards relating to bridges and drainage were later combined. Truck escape ramps are a special hazard that was added later. See table 1 for the list of hazardous areas.

Table 13. Hazard ranks.

Hazard	Overall Ranking	Urban Freeway Rank	RSCE* Score	Rural Freeway Rank	RSCE Score	Urban Non-Freeway Rank	RSCE Score	Rural Non-Freeway Rank	RSCE Score
Most Serious									
Snow or ice accumulation at/on highside shoulder of superelevated ramps and superelevated curves without reverse shoulder slopes or rounded shoulder cross section.	1	1	252	1	216	2	189	1	180
Snow or ice accumulation at/on bridge parapets, rails or curb areas.	2.5	2	243	3	138	1	243	4	112
Vehicles colliding with snow plows or other snow removal equipment.	2.5	3	192	2	192	3	144	2	168
Reduced sight distance due to snow piled at curves, intersections, and interchanges.	4	4	110	4	129	4	105	3	120
Serious									
Snow or ice accumulation at/on guardrail.	5	5	81	5	68	7	53	9	32
Improper alignment of snow plow causing traffic following plowed path to drive off traveled way, or decreasing usable lane width.	6	7	75	6	60	9.5	38	5	75
Stalled or abandoned vehicles impeding proper emergency snow removal and post-snowstorm cleanup operations.	7	9	54	7	54	9.5	38	6	54
Lack of snow storage areas at narrow medians, shoulders, and gores.	8	8	66	8	45	8	45	10	31
Snow or ice accumulation at/on concrete median barriers.	9	6	80	10	16	5	74	16	4

* The product of risk, severity, correctability, and exposure.

Table 13. Hazard ranks (concluded).

Hazard	Overall Ranking	Urban Freeway Rank	RSCE* Score	Rural Freeway Rank	RSCE Score	Urban Non-Freeway Rank	RSCE Score	Rural Non-Freeway Rank	RSCE Score
Important Ranked									
Snow or ice accumulation at/on recessed or indented drains, and culverts, and channels.	10	10	28	9	23	11.5	36	7	38
Snow or ice windrow buildup at exit ramps, on-ramps and intersections. Windrows resulting from plowing across entrance or exit ramps or along the roadway.	11.5	14.5	10	13	10	13	30	12	23
Blocked drainage where snow melt forms water pools (such as from windrows at sag veritcal curves) during the day which may turn into ice patches at night.	11.5	12.5	12	12	12	15	16	13	16
Snow or ice accumulation at/on side slopes adjacent to shoulders with shallow cuts.	13	18	-0-	11	14	17.5	8	8	35
Snow or ice accumulation at/on railroad crossings.	14	N/A	N/A	N/A	N/A	6	56	11	30
Pavement obstructions such as raised islands, rumble strips, curbs, delineators, buttons, joints, and covers that inhibit snow and ice removal.	15	16	9	14	9	12	36	14	14
Snow or ice accumulations at/on curbs, raised medians, raised shoulders, raised gore areas, walkways on bridges, and elevated support for guardrail.	16	14.5	10	16	4	14	24	17	4
Snow obscuring highway signs.	17	17	5	15	5	16	9	15	9
Snow or ice accumulation at/on impact attenuators or attenuator mechanism jammed with snow or ice.	18	12.5	12	17	3	17.5	8	18.5	-0-
Snow plows casting snow from overhead bridges with inadequate snow storage areas onto adjacent roadways or properties.	19	11	14	18	2	19	7	18.5	-0-

* The product of risk, severity, correctability, and exposure.

APPENDIX C - CLEANING SNOW FROM SAFETY-SHAPED BARRIERS

This appendix presents FHWA troubleshooter publication No. 83-1, June 1983) [67] describing a rubber plow-blade attachment for cleaning snow from safety-shaped barriers. The attachment was developed by the Brown County, Wisconsin, highway agency. The device costs about $250 (1987 dollars) to construct. The mounting assembly (figure 1 of this appendix) has been redesigned and now includes a diagonal support brace between the "flat iron" and "angle" sections.

U.S. Department
of Transportation
**Federal Highway
Administration**

Snow Removal from Concrete Safety Barriers Troubleshooter No. 83-1

June 1983

Information Furnished by:

Wisconsin Department of
Transportation
District 3
944 Scenic Way
Green Bay, Wisconsin 54304

Safety Shaped Concrete Barrier - Snow Removal

The safety shaped concrete barrier is designed for use on bridges and in medians to redirect an errant vehicle away from a hazard. The effectiveness of this device is negated when there is an accumulation of snow in front of the barrier. The hard packed snow changes the shape of the barrier which can cause a vehicle to vault into the hazard rather than being redirected away from it.

Conventional plow blades leave a wedge of snow against the sloped face of the barrier. Total removal of the snow from the barrier is costly when the work is performed by hand methods. Further, hand methods require a considerable amount of time which delays the completion of the snow removal and extends the length of time the barriers are in a hazardous condition.

Brown County in the Wisconsin Department of Transportation Green Bay District has developed an attachment for the conventional plow blade for cleaning the safety shaped barriers. The attachment consists of a 1-1/2" thick rubber panel which has been templated to the sloped face of the barrier.

The front and side views of the rubber panel assembly attached to a conventional snow plow blade are shown in the photographs below.

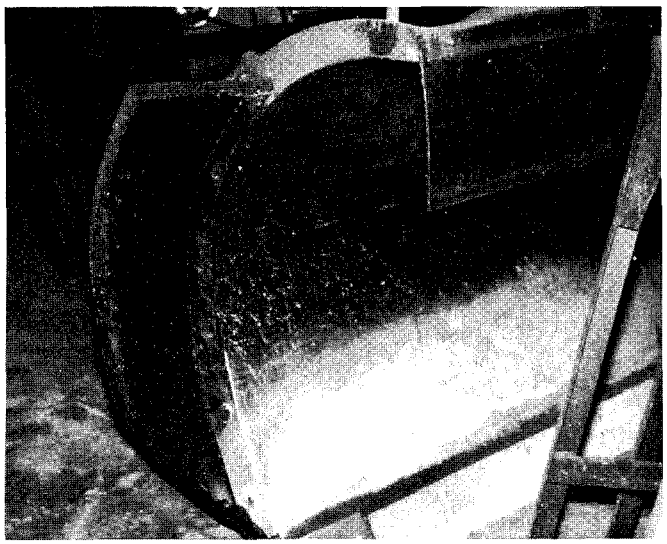


Photo A

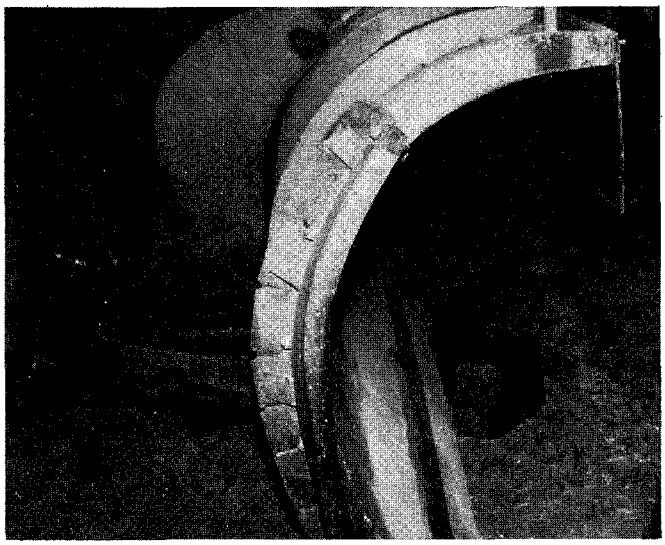
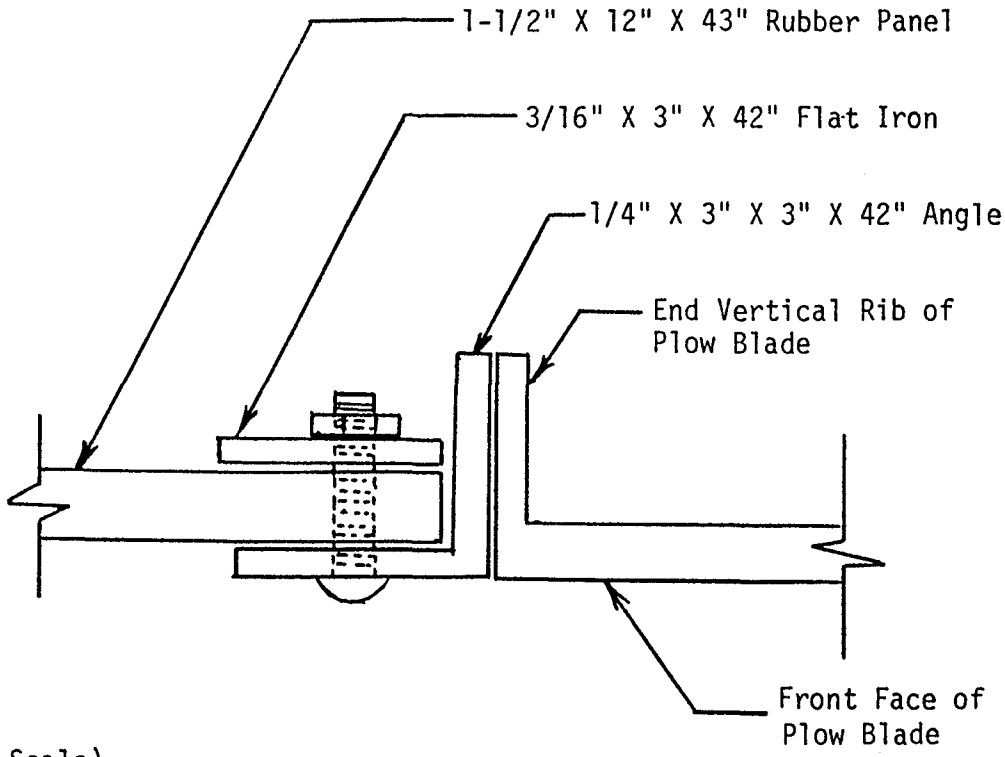


Photo B

A 1/4" X 3" X 3" X 42" angle is used to attach the rubber panel to the plow. The rubber panel is cut to conform to the shape of the barrier (see Photo "A"). In order to bend the angle so it conforms to the contour of the plow blade, relief cuts are made every 5" in the vertical leg (see photo "B"). The rubber panel is attached to the angle using a 3/16" X 3" flat iron. Five 1/2" X 2-1/4" bolts with 1/2" hex. nuts are used to fasten the assembly together. The assembly is then welded to the end vertical rib of the plow. A sketch of the assembly is shown below:



(Not to Scale)

FIGURE 1 Cross Section of Plow Blade with Rubber Panel Assembly Attachment

The rubber panel is expected to provide 3 to 5 years of service before it has to be replaced. Note the wear on the panel, shown in Photo "B", which is about 3-years-old.

A list of the materials necessary to construct the rubber panel attachment include:

1 piece 1-1/2" X 12" X 43" rubber panel
1 piece 1/4" X 3" X 3" X 42" angle
1 piece 3/16" X 3" X 42" flat iron
6 pieces 1/2" X 2-1/4" bolts
6 pieces 1/2" hex. nuts

The materials cost, based on 1981 prices, was $85.00. Four hours of labor are required to fabricate the assembly and mount it on the plow. Labor costs vary. The cost for Brown County was about $55.00 in 1981.

One disadvantage of the plow attachment is that it removes the reflectors which delineate the face of the barrier. The replacement reflectors are mounted on the top of the barrier near the right edge. The plows equipped with the rubber attachment on one side only have the added disadvantage that they have to work against traffic on multi-lane divided highways. The lane closure is accomplished with a flashing arrow board mounted on a pickup truck. Some of the plow blades are equipped with the rubber panel assembly on both sides in order to avoid the plowing against traffic.

Conclusion

The use of a templated rubber attachment to the snowplow blade has been found to be an effective means for snow removal from the face of safety shaped barriers. The attachment is easy to construct and inexpensive. This technique works well for barriers, particularly on structures, that are in the 150' range. For those longer than 150', loading and hauling of snow may be required.

Our appreciation goes out to Area Engineer Richard C. Madrzak of the Wisconsin Division for preparing this report and the Wisconsin DOT for providing the information.

APPENDIX D - MINNESOTA DISTRICT 9 SNOW AND ICE REMOVAL PLAN

This appendix presents an excerpt of the Minnesota Department of Transportation District 9 Snow and Ice Removal Plan. (29)

Priorities

Our District Plowing and Sanding Policy is to clear the main roadways, loops, ramps, acceleration and deceleration lanes, turn lanes, bridges, and emergency cross-overs as provided in our Statewide snow and ice standards. This standard provides for over-time work until roadways meet our level of services definition.

Cleanup Priorities (After Storm)

Normally cleanup will not be done when temperature is below -20 degrees F.

Priority A - (1) Clearing crash rail, Jersey Barrier or similar type rails on super commuter routes and urban commuter routes - work over-time if snow is 2/3 the height of barrier. When height is less than 2/3, remove during regular hours as work load permits. (This includes bridge crash rails.) Holidays & Sundays are excluded from this work schedule.

(2) Clearing crash rail, Jersey Barrier or similar type rails on rural commuter routes when height of snow is 2/3 height of barrier or higher during regular hours. (This included bridge crash rails.)

(3) Clear in front of and around, impact attenuator when snow is 2/3 height of the impact attenuator. Work over-time if necessary.

(4) Four lane at grade crossing, work over-time if necessary

(5) Diamond interchange, work over-time if necessary

(6) Cloverleaf interchange, work over-time if necessary

(7) Two lane at grade crossing, work over-time if necessary

Priority B - Clear full shoulder width during regular working hours. Over-time permitted if weather forecast warrants.

Priority C - Drift prevention for future storms during regular working hours.

Over-time permitted if weather forecast warrants.

Priority D - Regaining storage space for future snow storms during regular hours.

State-owned equipment shall not be used to tow stalled or disabled vehicles (this does not apply to stalled or disabled MN/DOT vehicles) to garages or back onto the roadway. All towing should be performed by responsible private individuals.

Employees should offer reasonable emergency aid to occupants of disabled vehicles. Where wrecker service, mechanical attention or services of the highway patrol are required, the employee should attempt to make such arrangements via mobile radio, if requested. When authorized, employees may remove stalled vehicles from the road if they present a hazard to traffic or maintenance operations. In extreme emergencies, with authorization of the supervisor on duty, employees may use State owned equipment to transport occupants of disabled vehicles to a safe place.

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